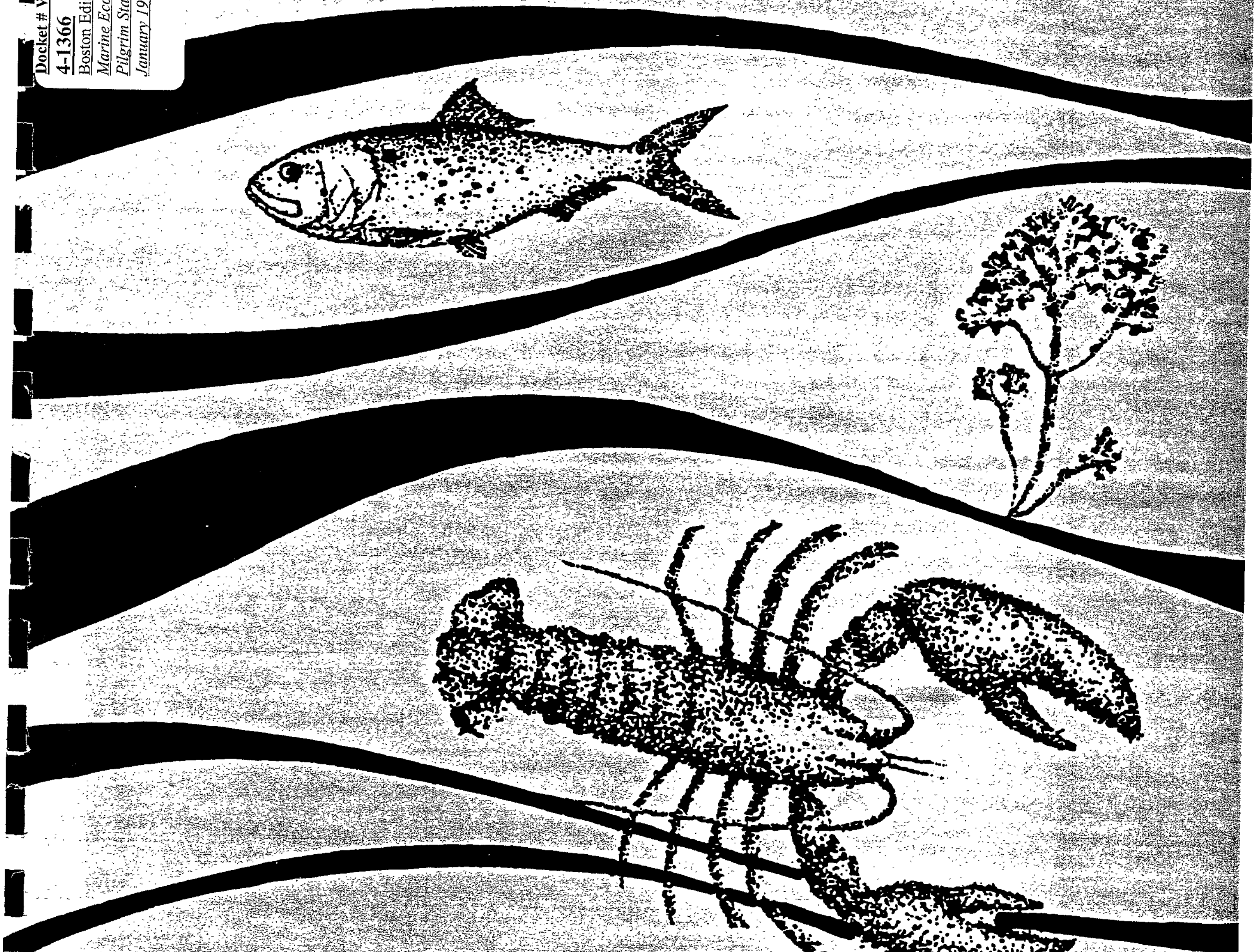
25829 Intake Case studies: Pilgrim

marine ecology studies
Related to Operation of Pilgrim Station

SEMI-ANNUAL REPORT NUMBER 41
JANUARY 1992 – DECEMBER 1992



BOSTON EDISON COMPANY
LICENSING DIVISION

BOSTON EDISON
800 Boylston St. Boston, MA 02199

BOSTON EDISON
25 Braintree Hill Park
Braintree, Massachusetts 02184

APR 26 1993

W. C. Rothert
General Manager Technical

April 23, 1993
BECo 93-057

NPDES Program Operations Section (WCP)
Environmental Protection Agency
P.O. Box 8127
Boston, MA 02114

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

Dear Sirs:

In accordance with Part I, Paragraphs A.8.b & e, and Attachment A, Paragraph I.F, of the Pilgrim Nuclear Power Station NPDES Permit No. MA0003557 (Federal) and No. 359 (State), Semi-Annual Marine Ecology Report No. 41 is submitted. This covers the period from January through December 1992.

W. C. Rothert

Attachment: Semi-Annual Marine Ecology Report No. 41

RDA/cab/6287

MA 3557

BOSTON EDISON
25 Braintree Hill Park
Braintree, Massachusetts 02184

T. E. LAND

MAY 6 1993

W. C. Rothert
General Manager Technical

April 23, 1993
BECo 93-057

Mass. Division of Water Pollution Control
Regulatory Branch - 7th Floor
One Winter Street
Boston, MA 02108

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

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W. C. Rothert

Attachment: Semi-Annual Marine Ecology Report No. 41

RDA/cab/6287

cc: Mass. Division of Water Pollution Control
Lakeville Hospital
Lakeville, MA 02346

BOSTON EDISON
25 Braintree Hill Park
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W. C. Rothert
General Manager Technical

April 23, 1993
BECo 93-057

NPDES Program Operations Section (WCP)
Environmental Protection Agency
P.O. Box 8127
Boston, MA 02114

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

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W. C. Rothert

Attachment: Semi-Annual Marine Ecology Report No. 41

RDA/cab/6287

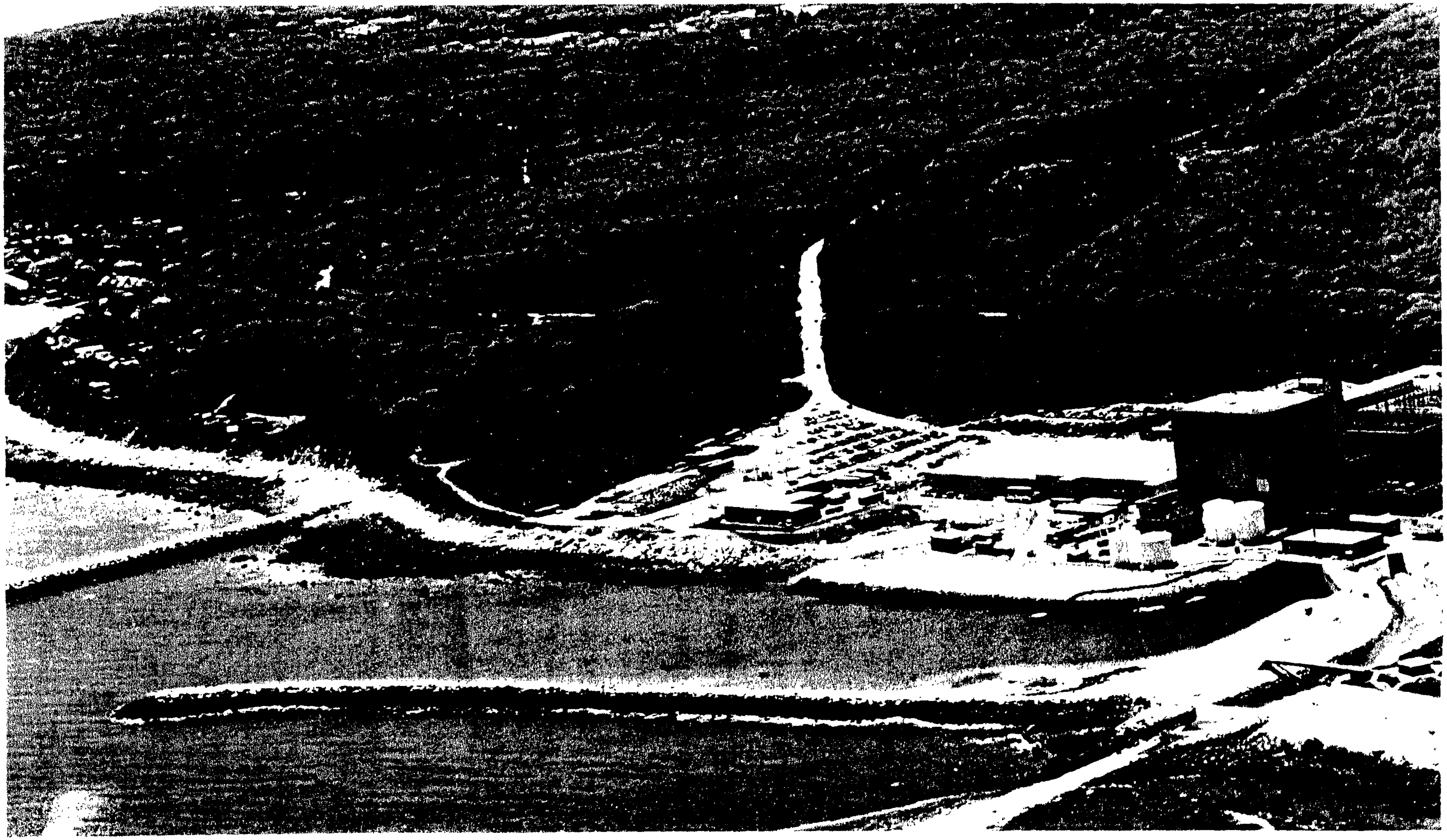
MARINE ECOLOGY STUDIES
RELATED TO OPERATION OF PILGRIM STATION

SEMI-ANNUAL REPORT NO. 41
REPORT PERIOD: JANUARY 1992 THROUGH DECEMBER 1992
DATE OF ISSUE: APRIL 30, 1993

Compiled and Reviewed by: Robert D. Anderson

Robert D. Anderson
Principal Marine Biologist

Licensing Division
Boston Edison Company
25 Braintree Hill Office Park
Braintree, Massachusetts 02184



Pilgrim Nuclear Power Station

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SUMMARY

Highlights of the Environmental Surveillance and Monitoring Program results obtained over this reporting period (January - December 1992) are presented below. (Note: PNPS was operating at high power level from January - December 1992 with the exception of outages during the first half of April and in November.)

Marine Fisheries Monitoring:

1. In the mid-April - late September 1992 shorefront sportfish survey at Pilgrim Station, 2,241 angler visits accounted for 892 fishes caught. Bluefish (85%) and striped bass (12%) dominated the sportfish catch. The presence of a strong thermal discharge component during most of 1990, 1991 and 1992 resulted in good sportfishery success compared with outage and low power years covering the shorefront angling season.

2. Pelagic fish mean CPUE (Catch Per Unit Effort) for 1992 at the gill net station (39.6 fishes/set) decreased 48% from 1991 to the lowest level recorded since 1971. Pollock (40%) and striped bass (18%) were 58% of the total catch. Only striped bass showed a meaningful increase from 1991. The 1990-1992 gill net catch rates for cunner have been the lowest since 1971 indicating a local population reduction for this species.

3. Shrimp trawl catch for 1992 recorded 28 benthic fish species with Atlantic herring (60%), little skate (44%), winter flounder (24%) and windowpane (18%) composing 86% of the total. Mean CPUE for all species was 23.8 (lowest) at the Priscilla Beach station, 44.0

(highest) at the Pilgrim Discharge station and 31.2 for all stations pooled in 1992. The presence of a large number of small winter flounder caught in the Pilgrim intake from 1984-1992 indicates this area may serve a nursery function for this species.

4. Adult lobster mean monthly catch rate per pot haul, in May - October 1992, was 0.25 lobsters which is 30% lower than the 1991 rate (0.37). The surveillance area (thermal plume) catch rate was 0.32 while the reference area (control) was almost half of this at 0.18. No significant correlation was noted between lobster catch rate for thermal plume areas, and mean seasonal Pilgrim Station output. The lobster catch data for control vs. thermal plume areas was not significantly different for the period 1983-1992. The lobster research study, which commenced in 1986, found no significant differences between plant MDC and lobster catch rates in 1992.

5. In May - October 1992 fish observational dive surveys, 8 species (631 fishes) were observed in the thermal plume area. Cunner (46%), striped bass (25%) and tautog (24%) were the most numerous fishes seen, the latter two species being most abundant in the direct path of the Pilgrim discharge current. Total number of fishes observed was 67% lower than in 1991, primarily because of fewer cunner observed. Most fishes were in greatest concentrations at stations in the discharge zone (65%), followed by the control zone (29%) and the stunted zone (6%). These results were different than 1984/1987/1988 (outage years with reduced discharge current), when most fish were observed relatively evenly divided between discharge and control zones, and

similar to 1985/1986/1989-1991 (higher discharge current years) when fish seemed to greatly favor being in the path of the effluent.

6. A total of 1,403 cunner were tagged in 1990-1992 and 226 (16%) recovered in the Pilgrim vicinity. Time at large and locations of recovered fish indicate that movement of this species is local which reflects its residential nature. Initial local population estimates of adult cunner residing in the Pilgrim intake breakwater vicinity are from 4,000-5,000 individuals.

Impingement Monitoring:

1. The mean January - December 1992 impingement collection rate was 0.63 fish/hr. The rate ranged from 0.05 fish/hr (June & July) to 1.69 fish/hr. (March) with Atlantic silverside comprising 47.3% of the catch, followed by winter flounder 14.7%, grubby 8.8% and rainbow smelt 5.1%. Fish impingement rates in 1985, 1986 and 1989 - 1992 were several times higher than in 1984, 1987 and 1988 when Pilgrim Station outages had both circulating water pumps off for various periods of time.

2. In February and March 1992, Atlantic silverside impingement accounted for 77% of this species annual collection. They have been the most abundant species impinged on an annual basis at Pilgrim Station in 9 out of the past 12 years.

3. The mean January - December 1992 invertebrate collection rate was 0.76/hr, with sevenspine bay shrimp (48.4%), horseshoe crabs (13.6%) and American lobster (11.8%) accounting for 74% of the

catch. Sixty-nine American lobsters were sampled. The invertebrate impingement rates in 1985, 1986 and 1989 - 1992 were similar to those recorded at Pilgrim Station during the 1987 and 1988 outage years, despite lower circulating water pump availability in the outage years.

4. Impinged fish, initial survival at the end of the Pilgrim Station intake sluiceway was approximately 45% during static screen washes and 47% during continuous washes. Four of the dominant species showed greater than 50% survival, overall.

Fish Surveillance:

Fish overflights in 1992 spotted all four major species categories: herring, Atlantic menhaden, Atlantic mackerel and baitfish. Many sightings of fish in the nearfield Pilgrim vicinity were made, mostly Atlantic herring and menhaden. On both April 6 and 12 over 100,000 pounds of herring, and in May and June several hundred thousand pounds of menhaden, were observed within a few miles of Pilgrim Station. None of these occurrences were reported to regulatory authorities as they were not within 1/2 mile of the discharge canal.

Benthic Monitoring:

Four observations of the near-shore acute impact zones were performed during this reporting period. Denuded and stunted zone boundaries were indistinguishable during September 1987 - June 1989 discharge surveys as a result of the PNPS shutdown. These surveys noted delineated, denuded impact areas in fall 1989 - 1992, primarily because two circulating water pumps were in operation most of the time, resulting in maximum discharge current flow. The area of PNPS-induced scouring impacts varied from 996 m^2 (April) to 1,569 m^2 (September) in 1992.

Entrainment Monitoring:

1. A total of 36 species of fish eggs and/or larvae were found in the January - December 1992 entrainment collections (19-eggs, 33-larvae).

2. Seasonal egg collections for 1992 were dominated by winter flounder and American plaice (winter - early spring); Atlantic mackerel and labrids (late spring - early summer); labrids and rockling/hakes (late summer - autumn).

3. Seasonal larval collections for 1992 were dominated by rock gunnel and sand lance (winter - early spring); sand lance and fourbeard rockling (late spring - early summer); hakes and fourbeard rockling (late summer - autumn).

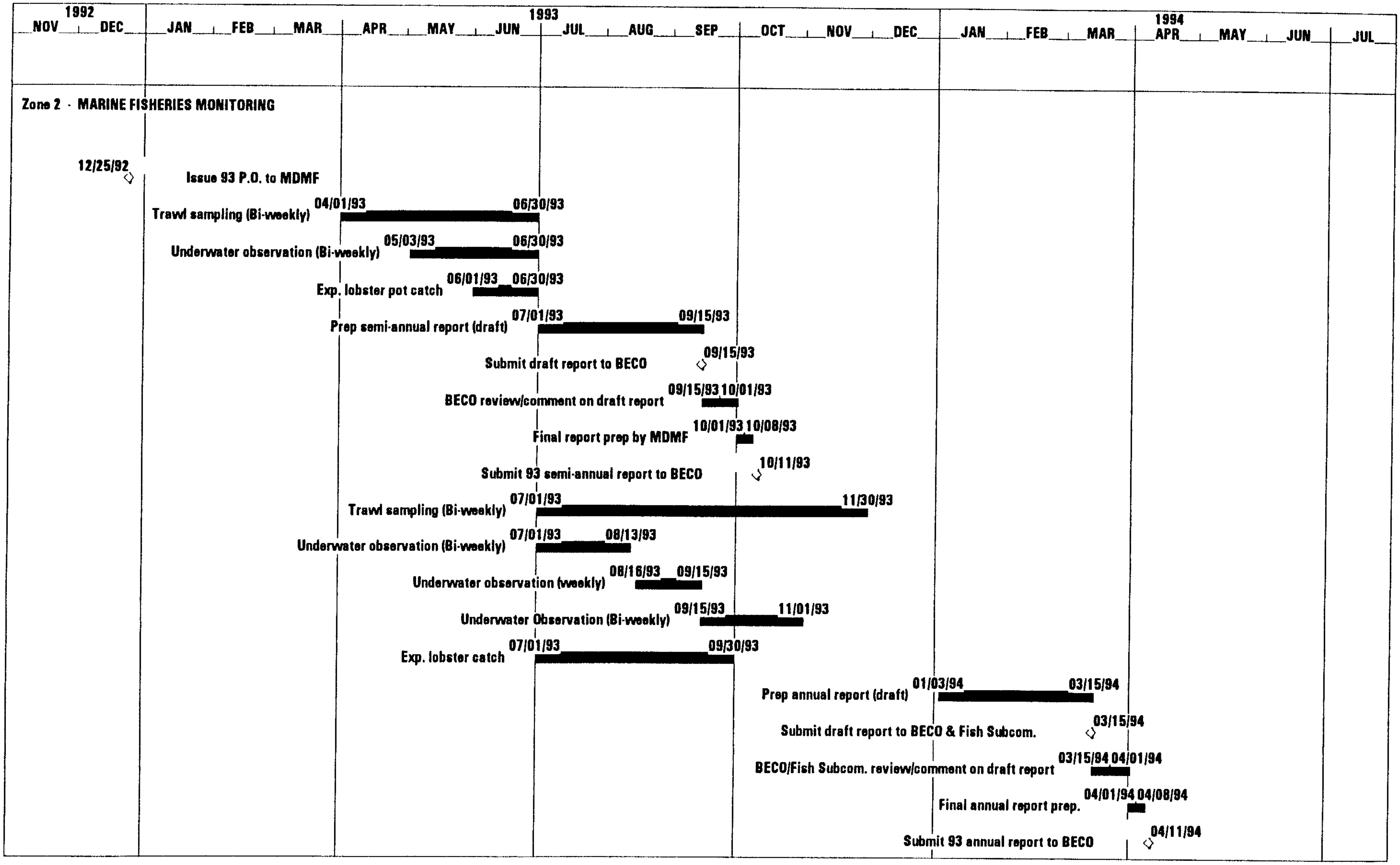
4. No lobster larvae were collected in the entrainment samples for 1992.

5. In 1992 an estimated 2.530×10^9 fish eggs and 2.461×10^8 fish larvae were entrained at Pilgrim Station, assuming full flow capacity of all seawater pumps. On an annual basis, eggs were dominated by Atlantic mackerel and the labrid - Pleuronectes group, and larvae by sand lance sp.

6. Total numbers of fish larvae collected for similar volumes of water sampled in spring/summer 1983 - 1992 were noteably different. These results were shown significant to the fact that Pilgrim Station circulating water withdrawal rate (number of pumps operating) affects number of larvae entrained; however, fish eggs appear relatively unaffected by this variable.

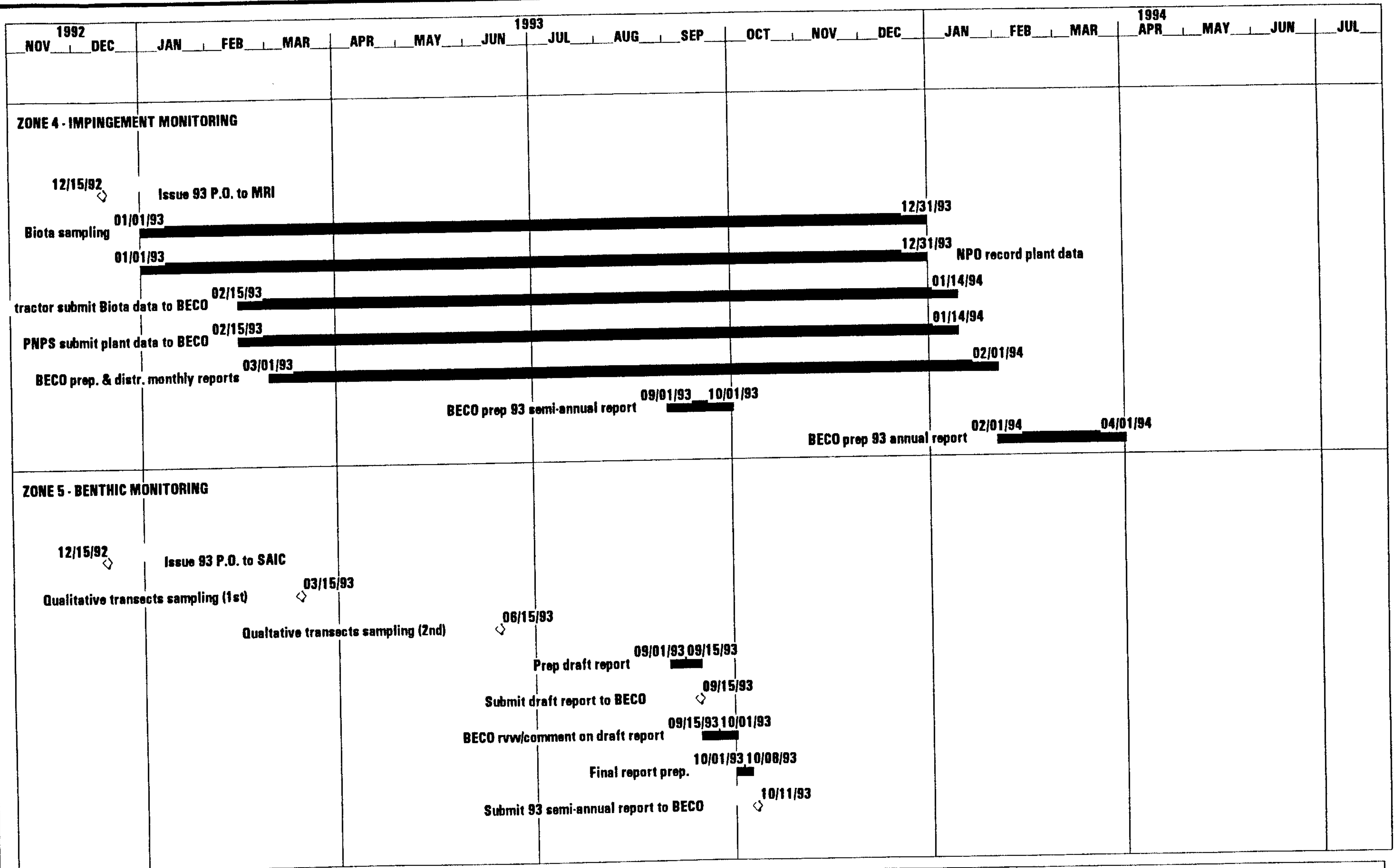
7. On no occasions in 1992 were "unusually abundant" ichthyoplankton densities recorded in samples, as defined by the entrainment contingency sampling plan.

8. The mean annual losses attributable to PNPS entrainment for the adult stage of three species of fish over the period 1987-1992 were as follows: cunner - 54,763; Atlantic mackerel - 6,496; winter flounder - 628. None of these losses for the species concerned were found to be significant in the context of population or fishery effects.



PNPS 1993 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT # MA0003557)



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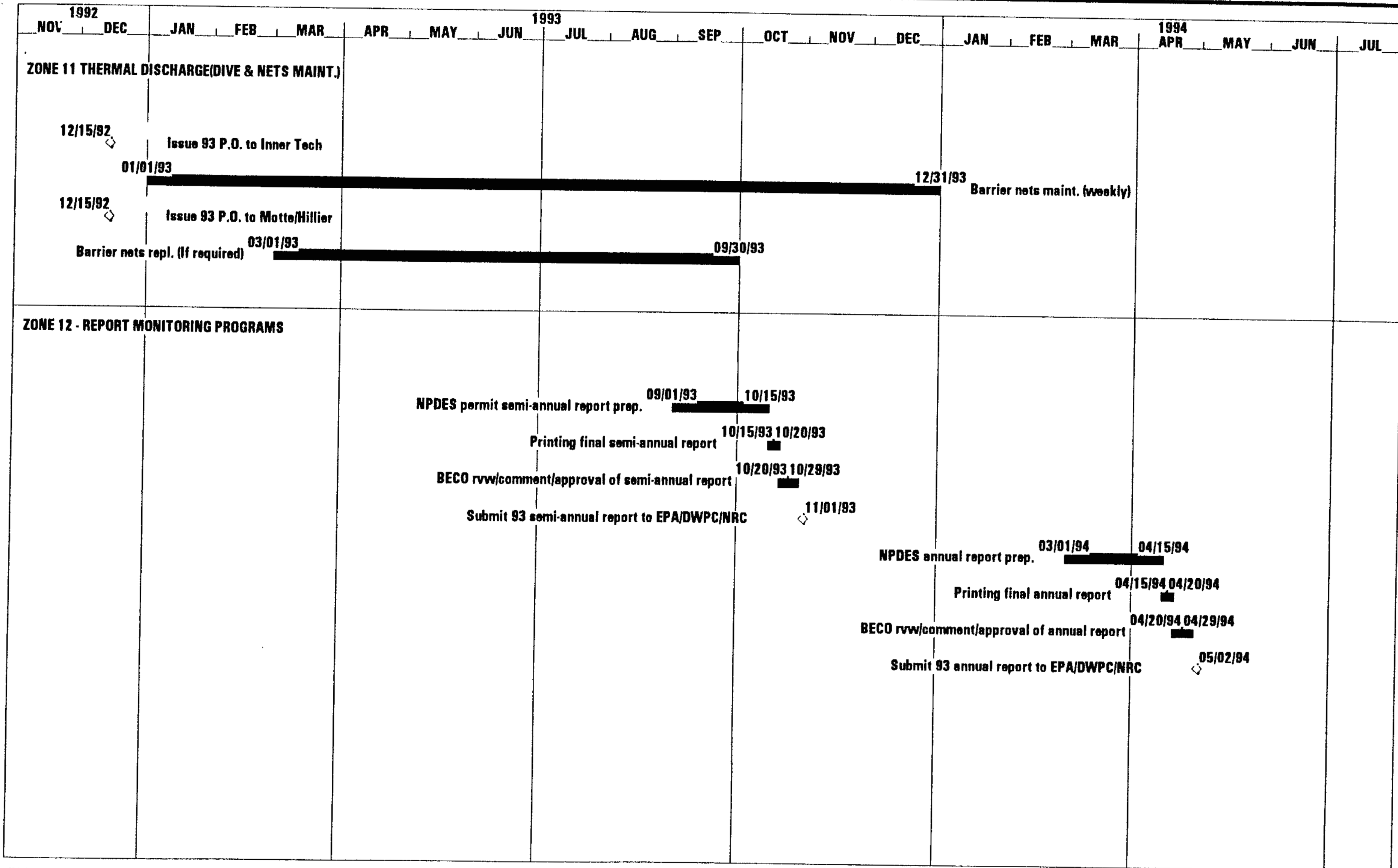
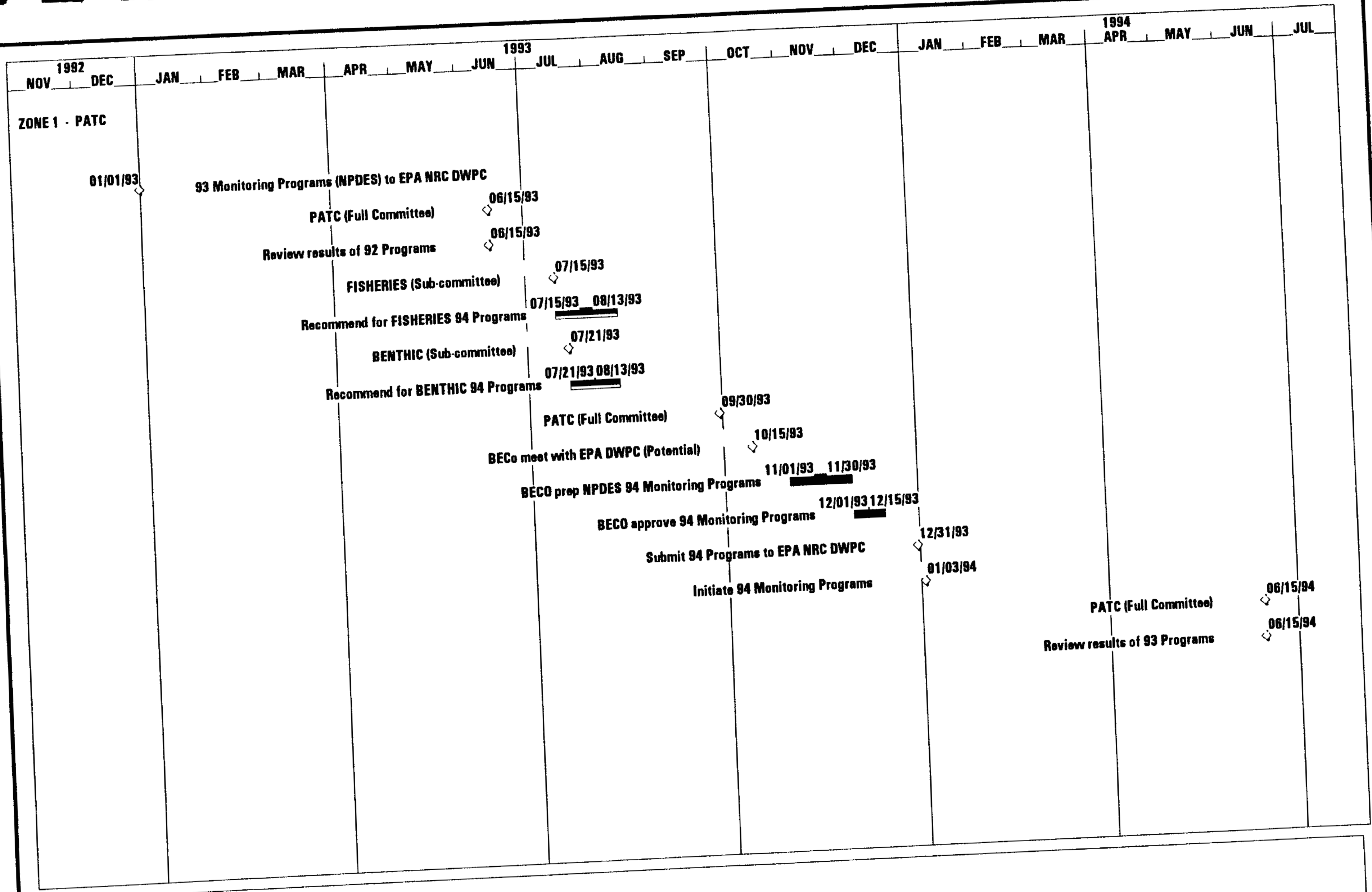


PNPS 1993 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT # MA0003557)



PNPS 1993 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT # MA0003557)

INTRODUCTION

A. Scope and Objective

This is the forty-first semi-annual report on the status and results of the Environmental Surveillance and Monitoring Program related to the operation of Pilgrim Nuclear Power Station (PNPS). The monitoring programs discussed in this report relate specifically to the Cape Cod Bay ecosystem with particular emphasis on the Rocky Point area. This is the twenty-ninth semi-annual report in accordance with the environmental monitoring and reporting requirements of the PNPS Unit 1 NPDES Permit from the U.S. Environmental Protection Agency (#MA0003557) and Massachusetts Division of Water Pollution Control (#359). A multi-year (1969-1977) report incorporating marine fisheries, benthic, plankton/entrainment and impingement studies was submitted to the NRC in July 1978, as required by the PNPS Appendix B Tech. Specs. Programs in these areas have been continued under the PNPS NPDES permit. Amendment #67 (1983) to the PNPS Tech. Specs. deleted Appendix B non-radiological water quality requirements as the NRC felt they are covered in the NPDES Permit.

The objectives of the Environmental Surveillance and Monitoring Program are to determine whether the operation of the PNPS results in measurable effects on the marine ecology and to evaluate the significance of any observed effects. If an effect of significance is detected, Boston Edison Company has committed to take steps to correct or mitigate any adverse situation.

These studies are guided by the Pilgrim Administrative-Technical Committee (PATC) which was chaired by a member of the Mass. Division of Water Pollution Control in 1992, and whose membership includes representatives from the University of Massachusetts, the Mass. Division of Water Pollution Control,

PNPS 1993 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT # MA0003557)

Timeline: 1992 NOV – DEC; 1993 JAN – DEC; 1994 JAN – JUL

Task	Start	Finish
MRI final report prep.	10/01/93	10/08/93
Submit 93 semi-annual report to BECO		10/11/93
Plankton sampling by MRI (weekly)	07/01/93	09/30/93
Sample processing & data analysis	10/01/93	10/29/93
Submit data analysis sheets to BECO		11/01/93
Plankton sampling by MRI (Bi-weekly)	10/01/93	12/31/93
Sample processing & data analysis	01/03/94	01/31/94
Submit data sheets to BECO		01/31/94
MRI prep annual report (draft)	02/01/94	03/15/94
Rvw/comment by BECO	03/15/94	04/01/94
MRI final report prep.	04/01/94	04/08/94
Submit 93 annual report to BECO		04/11/94

ZONE 9 - THERMAL DISCHARGE (OVERFLIGHTS)

Task	Start	Finish
Issue 93 P.O. to Correggio		12/15/92
Fish observation overflights (weekly)	03/01/93	06/30/93
BECO prep 4-month report	07/01/93	07/15/93
Fish observation overflights (weekly)	07/01/93	11/30/93
BECO prep 5-month report	12/01/93	12/15/93
BECO prep 93 annual report	02/15/94	03/15/94

A finfish observational dive program was initiated in June 1978. SCUBA gear is utilized on biweekly dives from May-October (weekly mid-August to mid-September) at 6 stations (Figure 2) in the PNPS thermal plume area.

In 1986, an experimental, lobster pot trawl monitoring effort was initiated to eliminate any biases associated with the collection of lobster stock catch statistics for determining PNPS effects. Ten 5-pot lobster trawls were fished in the thermal plume and control areas around PNPS during 1992 (Figure 3).

Results of the marine fisheries monitoring during the reporting period are presented in Section IIIA.1 and IIIA.2.

2. <u>Benthic Monitoring</u>

The benthic monitoring described in this report was conducted by Scientific Applications International Corporation, Woods Hole, Massachusetts.

Quantitative benthic (rock substratum) sample collection was terminated in 1992 while retrospective program and physical thermal plume analyses are being conducted to recommend the most applicable future studies to be performed. Qualitative transect sampling off the discharge canal to determine the extent of the denuded and stunted algal zones was continued four times a year (March, June, September and December).

Results of the benthic monitoring and impact analysis during this period are discussed in Section IIIB.

3. Plankton Monitoring

Marine Research, Inc. (MRI) of Falmouth, Massachusetts, has been monitoring entrainment in Pilgrim Station cooling water of fish eggs and larvae, and lobster larvae (from 1973-1975 phytoplankton and zoo-plankton were also studied). Figure 5 shows the entrainment contingency sampling station locations to be sampled should the number of eggs/larvae entrained greatly exceed recorded historical averages. Information generated through this monitoring has been utilized to make periodic modifications in the sampling program to more efficiently address the question of the effects of entrainment. These modifications have been developed by the contractor, and reviewed and approved by the PATC on the basis of the program results. Plankton monitoring in 1992 emphasized consideration of ichthyoplankton entrainment. Results of the ichthyoplankton entrainment monitoring and impact analysis for this reporting period are discussed in Section IIIC.1 and IIIC.2.

4. Impingement Monitoring

The Pilgrim Station impingement monitoring and survival program speciates, quantifies and determines viability of the organisms carried onto the four intake traveling screens. Since January 1979, Marine Research, Inc. has been conducting impingement sampling with results being reported on by Boston Edison Company.

A new screen wash sluiceway system was installed at Pilgrim in 1979 at a total cost of approximately $150,000. This new sluiceway system was required by the U.S. Environmental Protection Agency and the Mass.

Division of Water Pollution Control as a part of NPDES Permit #MA0003557. Special fish survival studies conducted from 1980-1983 to determine its effectiveness in protecting marine life were terminated in 1984, and a final report on them appears in Marine Ecology Semi-Annual Report #23.

Results of the impingement monitoring and survival program, as well as impact analysis, for this reporting period are discussed in Section IIID.

C. Fish Surveillance Studies

March - November, weekly fish spotting overflights were conducted as part of a continuing effort to monitor the times when large concentrations of fish might be expected in the Pilgrim vicinity.

An annual summary report for this effort for 1992 is presented in Section IVA.

D. Station Operation History

The daily average, reactor thermal power levels from January through December, 1987-1992 are shown in Figure 6. As can be seen, PNPS was in a high operating stage during most of this reporting period with a 1992 capacity factor (MDC) of 80.6%.Cumulative capacity factor from 1973-1992 is 49.0%.

E. 1992 Environmental Programs

A planning schedule bar chart for 1993 environmental monitoring programs related to the operation of Pilgrim Station, showing task activities and milestones from December 1992 - June 1994, is included after Figure 6. Both marine fisheries haul seine and benthic quantitative monitoring activities were terminated in 1992.

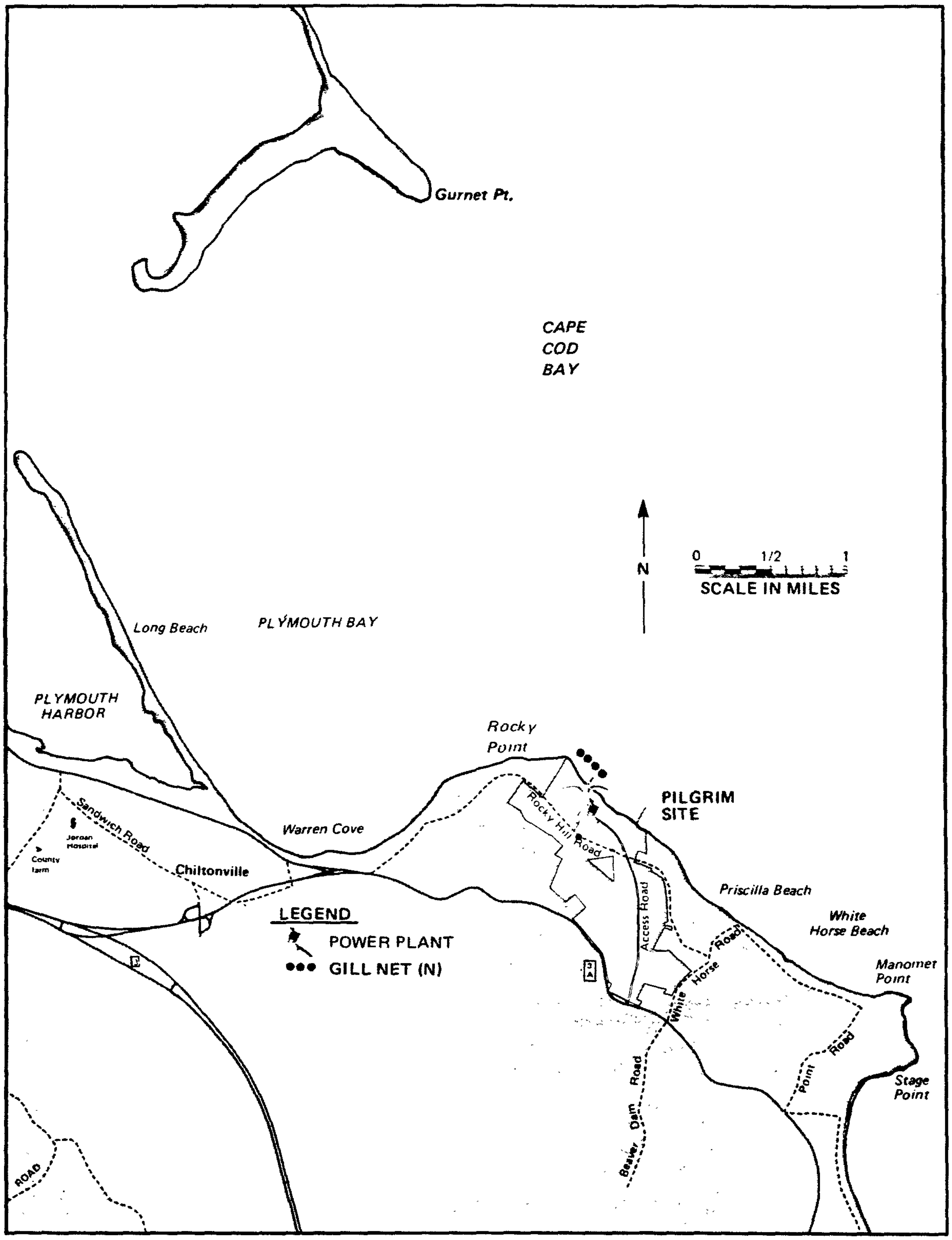


Figure 1. Location of Gill Net Sampling Station for Marine Fisheries Studies.

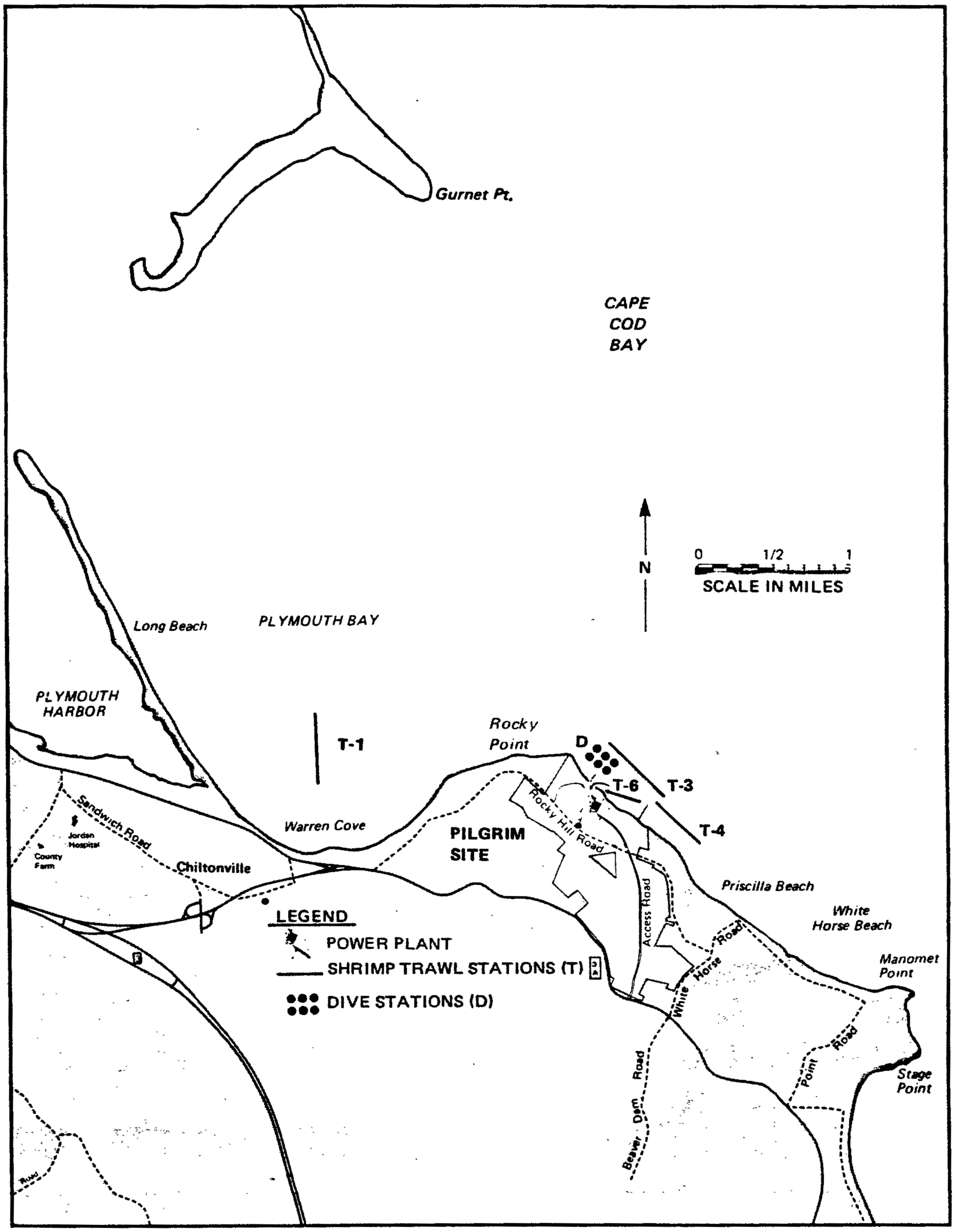


Figure 2. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies

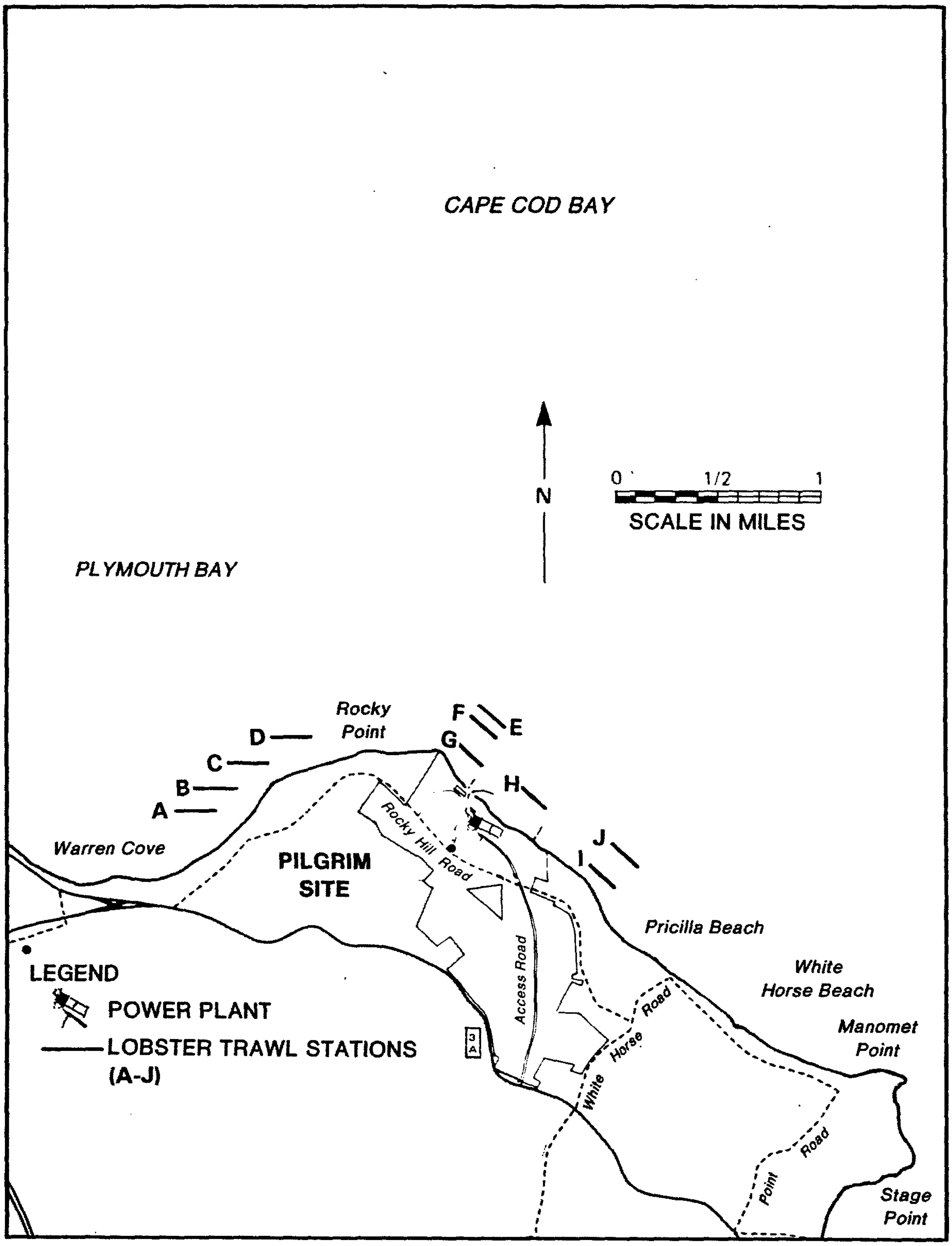


Figure 3. Location of experimental lobster gear (5-pot trawls) for Marine Fisheries Studies.

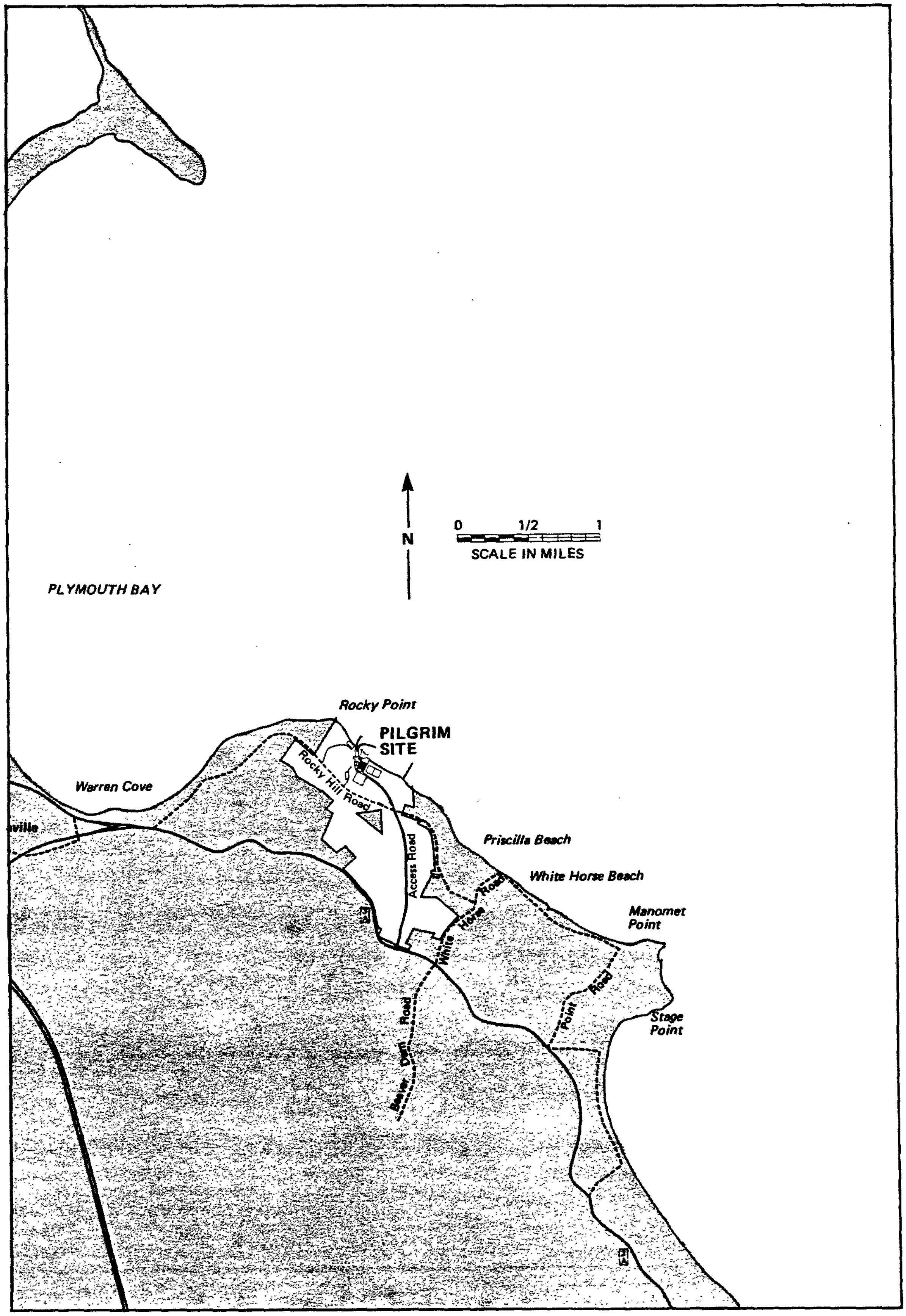


Figure 4 Lobster Pot Sampling Grid for Marine Fisheries Studies.

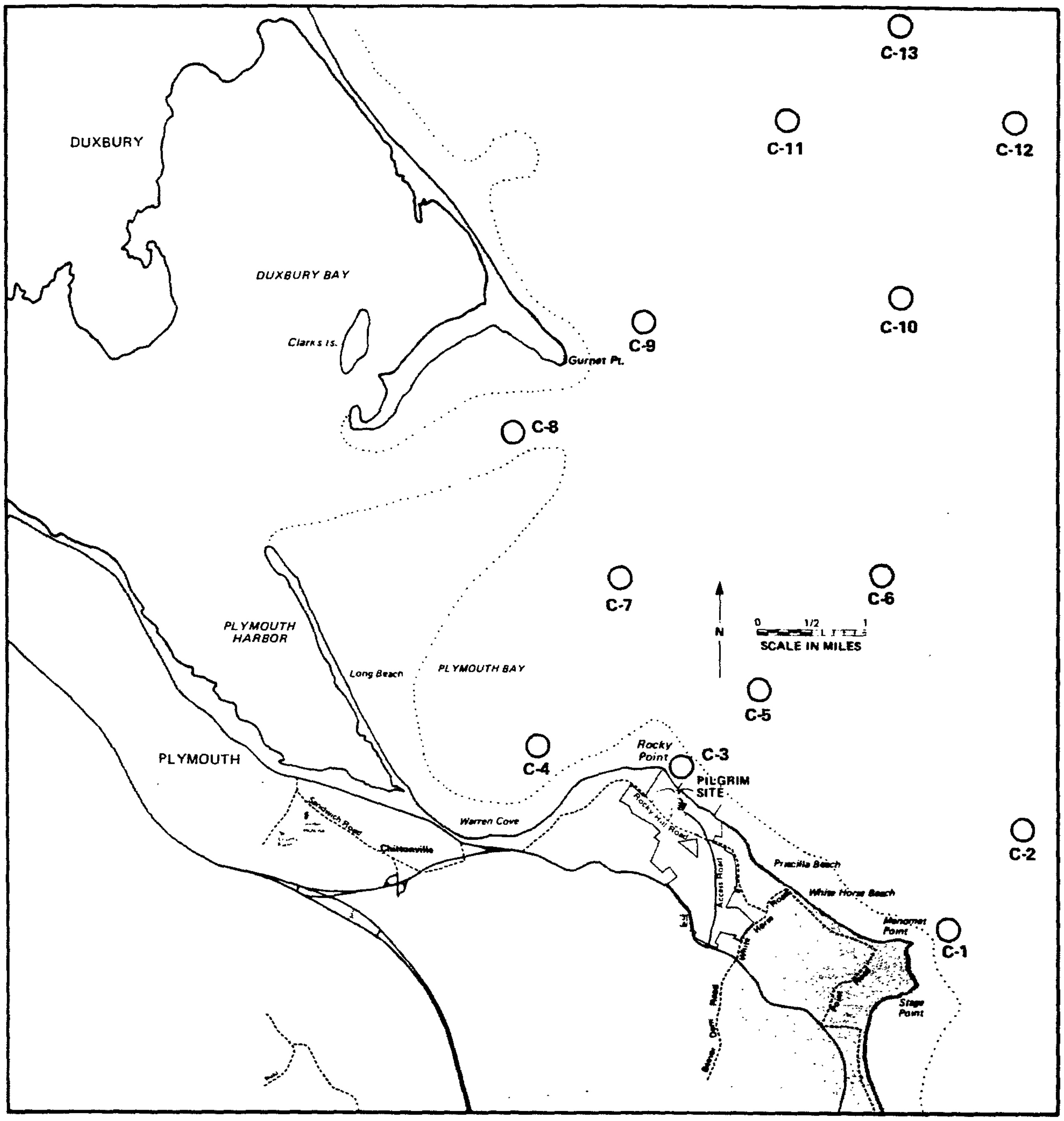
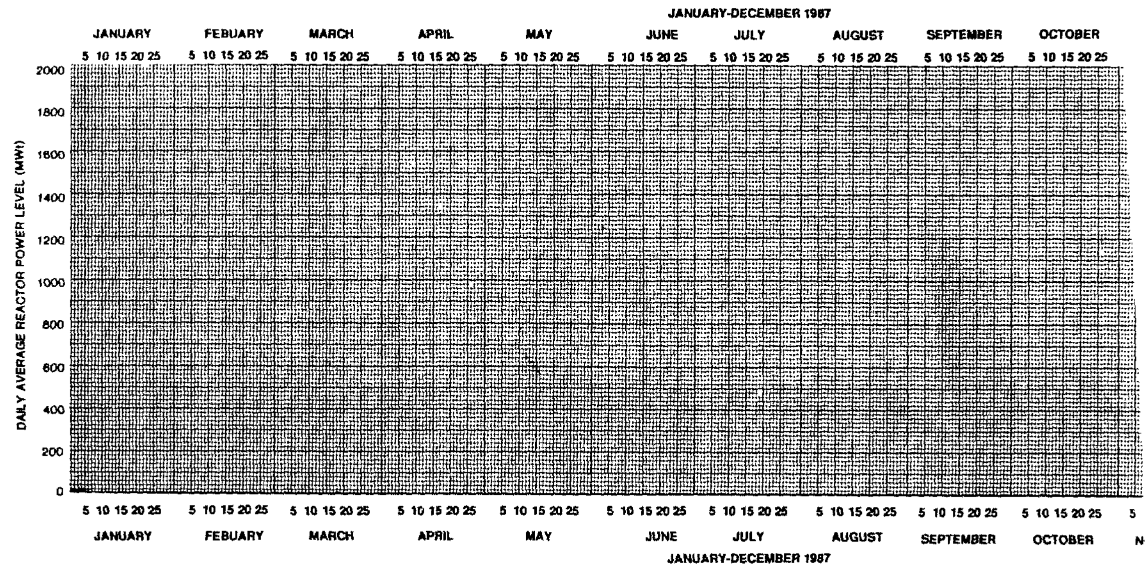
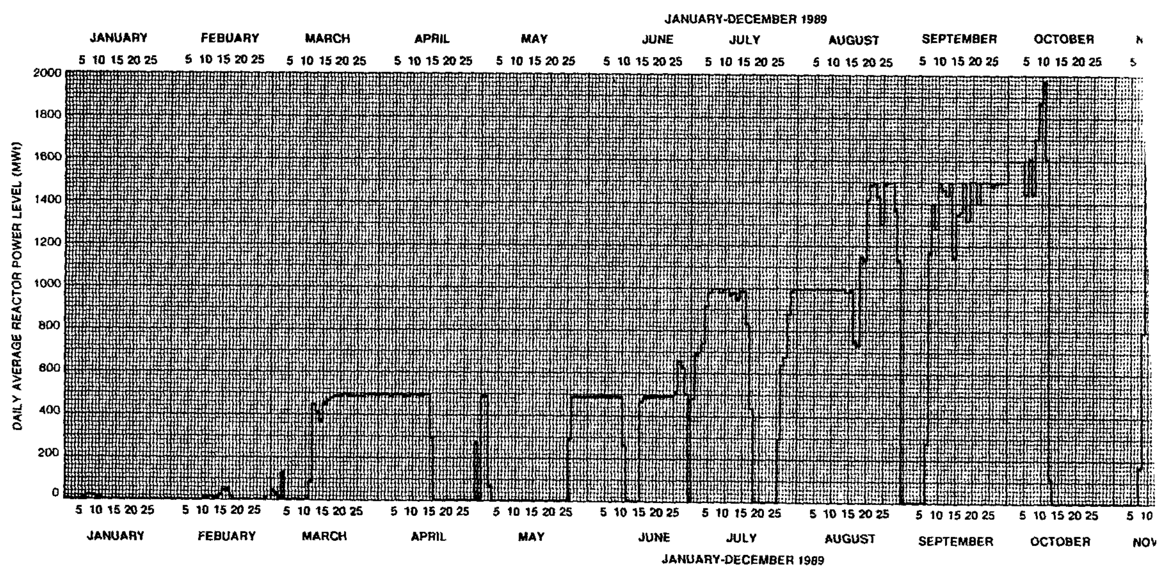


Figure 5. Location of Entrainment Contingency Plan Sampling Stations, C.





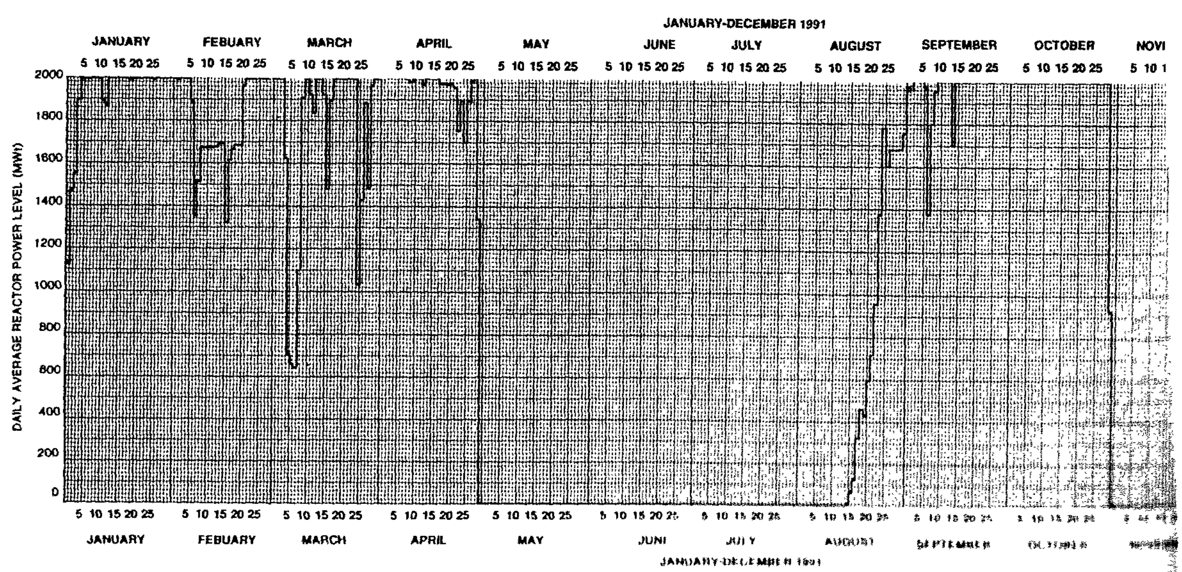
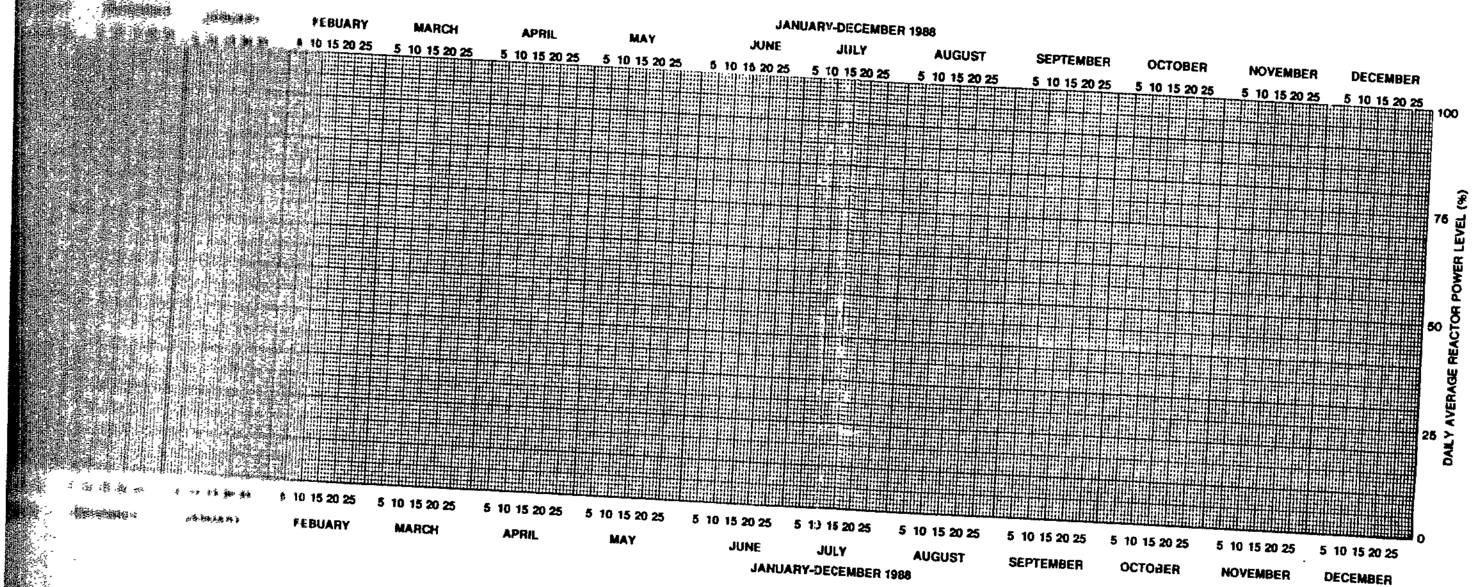


FIGURE 6 Daily Average R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APRIL
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JUNE
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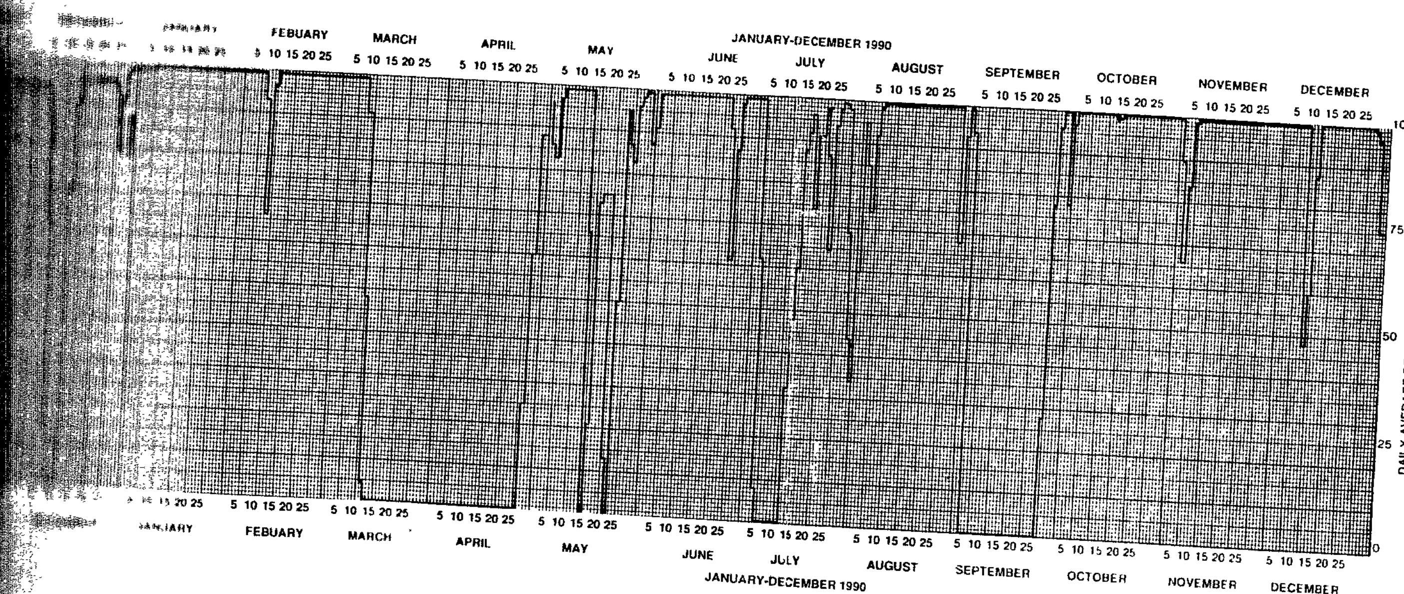
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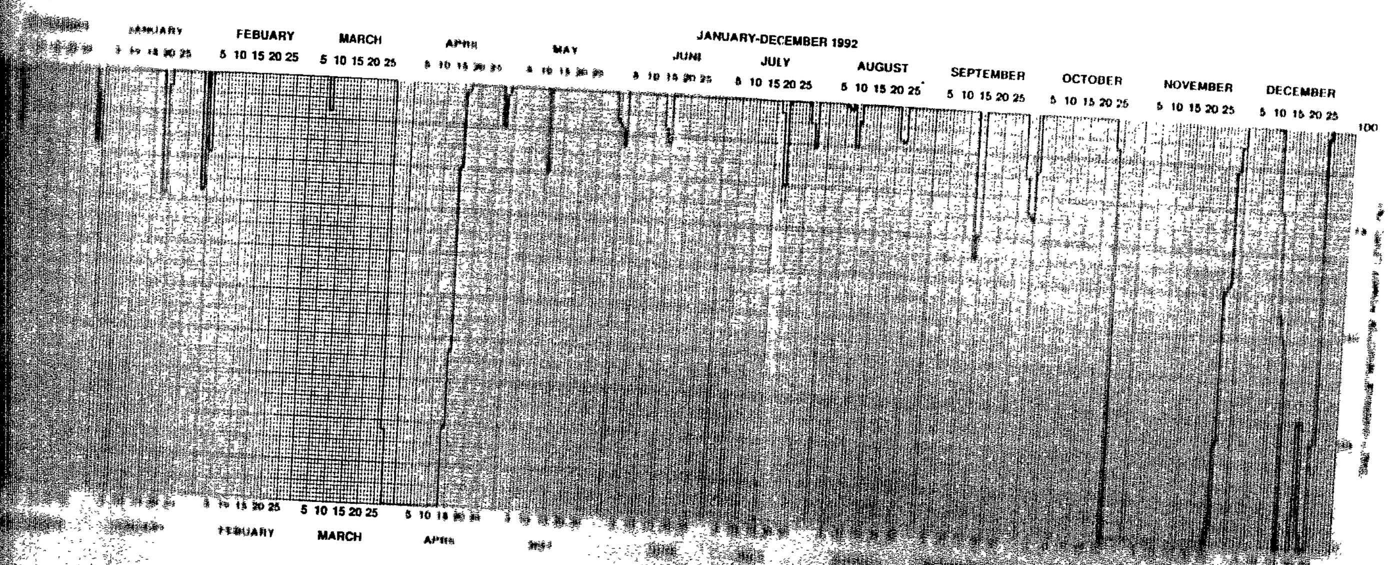
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SEPTEMBER
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DECEMBER
100

ANNUAL REPORT
ON
MONITORING TO ASSESS IMPACT
OF THE
PILGRIM NUCLEAR POWER STATION
ON THE MARINE FISHERIES RESOURCES
OF WESTERN CAPE COD BAY

(CHARACTERIZATION OF FISHERIES RESOURCES)

Project Report No. 54 (January-December, 1992)

(Volume 1 of 2)

By

Robert P. Lawton, Brian C. Kelly,
Vincent J. Malkoski, John Chisholm,
and Paul Nitschke

April 6, 1993
Massachusetts Department of Fisheries,
Wildlife, and Environmental Law Enforcement
Division of Marine Fisheries
100 Cambridge Street
Boston, Massachusetts 02202

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I. EXECUTIVE SUMMARY

A modified version of marine fisheries monitoring for Pilgrim Nuclear Power Station, initiated in 1981, was conducted by the Massachusetts Division of Marine Fisheries in 1992. The occurrence, distribution, and relative abundance of finfish and lobster were monitored according to standardized sampling schemes to identify trends and relationships in the sampling data collected from the study area over time. We focused our efforts on commercially and recreationally important fisheries resources. Nearshore bottom trawling, gill-net sampling, monitoring of local commercial lobster catch statistics, experimental lobster trapping, diver observations near the discharge canal and also along diving transects near trawl stations, cunner tagging, and a sportfishing creel survey rounded out investigations.

Three groundfish, winter flounder, little skate, and windowpane, comprised 86% of the total fish captured in the trawl survey. This first year of the diver transect survey found winter flounder to be particularly abundant in the Intake embayment. The overall gill-net catch rate (species pooled) for 1992 declined by a half from last year. The overall number of fish sighted during the discharge diving study decreased, due primarily to a substantial decline in the relative abundance of cunner. Angling effort at the Shorefront increased from last year, but the sportfish catch rate decreased slightly. Tagging returns indicate that there is limited summer movement of cunner off the outer intake breakwater at Pilgrim Station. Lobster catch rates in both the experimental and commercial studies declined this year, with legal catch rates declining more than that of sublegals.

II. INTRODUCTION

A field sampling program was conducted in 1992 by the Massachusetts Division of Marine Fisheries (DMF) to assess impact of Pilgrim Nuclear Power Station (PNPS) on the marine environment, under Purchase Order No. 69011 to Boston Edison Company (BECo). Our sampling employs various gear types and strategies to characterize the lobster and numerous finfish populations present in the Pilgrim area. Data were collected from impact and comparable reference stations. When possible, we have established more than one reference site to address natural variability.

The biological variables of interest are distribution, abundance, and size. We followed a standardized sampling regime and obtained measurements and counts, on which statistical tests were run.

Volume 1 focuses on characterizing the fisheries resources in the Pilgrim area as a whole. Essential findings are presented as our intent is to condense the subject matter and maintain clarity of data reporting and interpretation.

III. METHODS AND MATERIALS

For a comprehensive description of sampling station locations, gear and equipment, and the techniques employed in our monitoring program, the reader is referred to Semi-Annual Report No. 39 (January-December 1991): section 3: pp 3-11 in the report series entitled Marine Ecology Studies Related to Operation of Pilgrim Station published by Boston Edison Company. The overall study area is depicted in Figure 1. We will address here only those areas of change or modification to the existing program of study. Methods and materials are otherwise the same as those reported for 1991 in the above reference.

In our cunner tagging work of 1990 and 1991, our objective was to determine the general movements of cunner in the Pilgrim area. The tag we had selected for this work was a Floy FD-67F t-bar anchor tag with flag, 63.5 mm (2.5 in) in length, 0.01 g (4×10^{-4} oz), and colored red or blue (Figure 2). The flag of each tag was marked with a letter or number using an indelible pen to identify the tagging date. The two colors were used to differentiate the two tagging areas - the outer Intake breakwater and the Discharge. We found little movement of cunner during the warmer months of the year.

In 1992, our objective was to evaluate the assumptions and ultimately generate a population estimate with which to compare entrainment. To identify individual fish, we selected a modified tag for 1992. This tag was a 58 mm (2.3 in) Floy FD-68BC anchor tag, weighing 0.11 g (3.9×10^{-3} oz), with printed numbers,

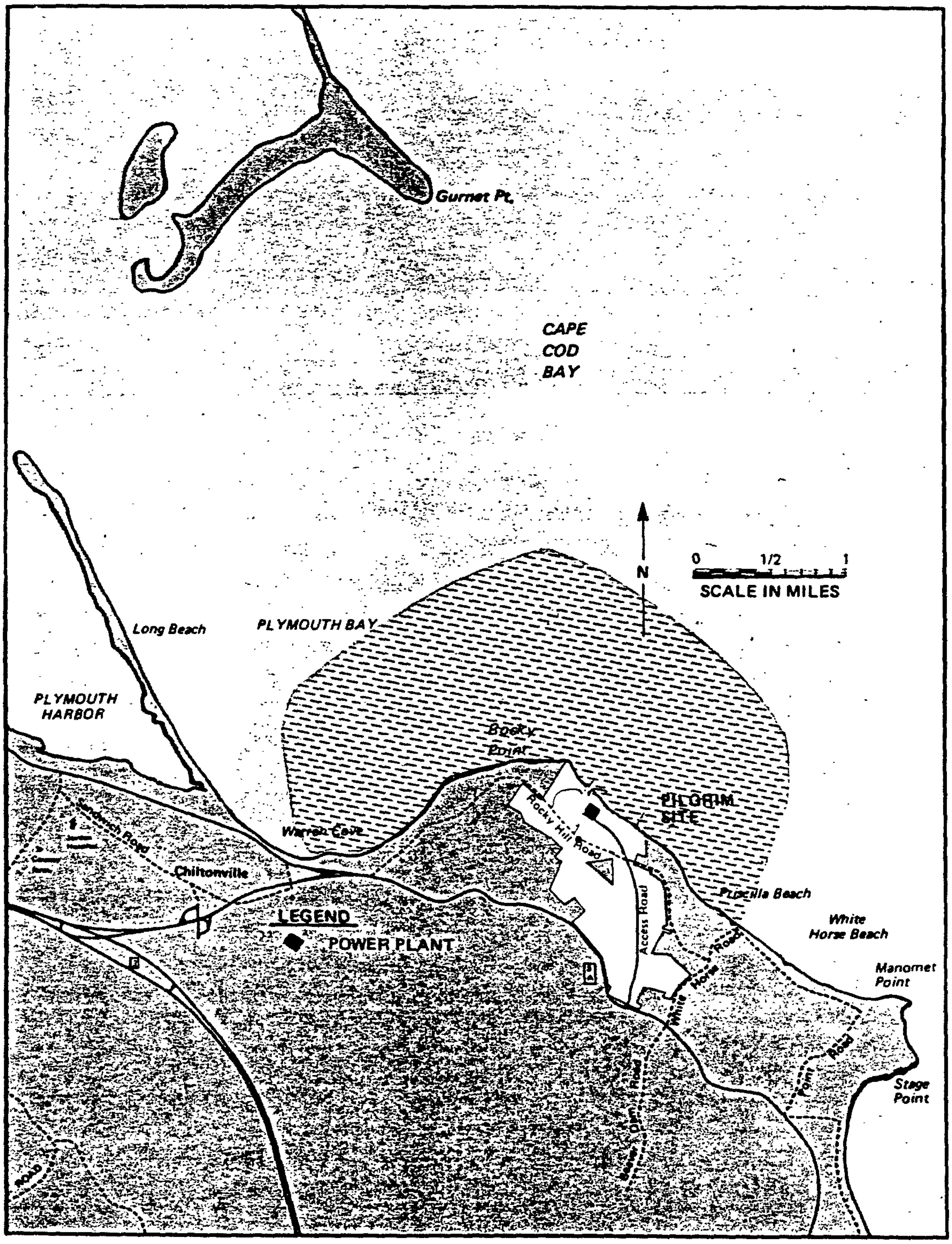

Figure 1. Location of Marine Fisheries study area (hatched) for trawl, cunner mark and recapture , gill net, lobster, dive, and sportfish surveys in the Pilgrim area.

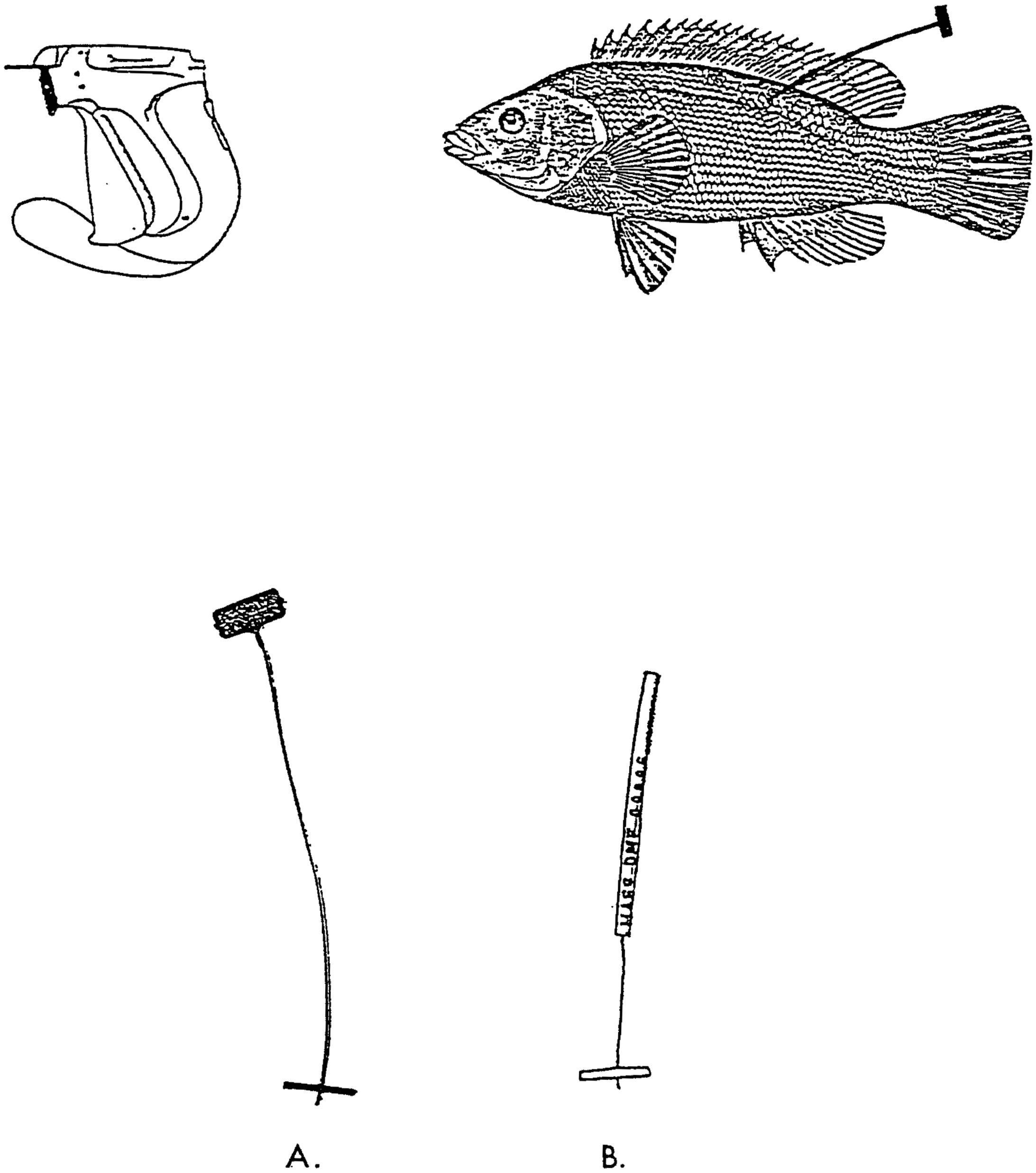

Figure 2. Tagging gun and two styles of t-bar anchor tags (A. in 1990 and 1991 and B. in 1992) used to mark cunner (shown above) off the Pilgrim Nuclear Power Station.

identifying agency, and phone number on #20 yellow tubing (Figure 2).

In our observational diving survey in 1992, we modified our technique in an effort to obtain more quantitative data which would allow a more rigorous analysis. Following the technique used by Bohnsack and Bannerot (1986) for assessing community structure among reef fishes, our divers moved to a station and remained motionless for five minutes, identifying any fish observed to the species level. The divers then moved to a back-to-back position and scanned the water column from surface to bottom, enumerating and estimating size frequencies for the previously identified fish. To avoid error caused by a diver recounting the same fish, the divers both rotated in a single direction during counting. Any schools of fish seen moving through the sampling area were identified and individually enumerated as soon as they were observed because of the transient nature of many schooling species. It is hoped that this technique will reduce the variability of our counts that can result from the disturbance caused by divers arriving on station and any movement during the actual survey.

To augment our sampling of the dominant groundfish in the study area in 1992, we implemented SCUBA diver transect surveys at the locations of three of our fixed trawl stations: Station 3 in the Discharge, Station 4 off Priscilla Beach, and Station 6 in the Intake. We patterned our equipment and techniques after Walton and Bartoo (1976). A T-shaped sampling device is pushed ahead of the divers' swim-track to define the observation area and to disturb the sediment, causing fish to rise off the bottom for counting. The sampler has a wooden handle, 3.2 cm diam. and 1 m long, with a 2 m perpendicular head made of 1 cm diam. aluminum rod. Aluminum washers (2.2 cm) have been threaded onto the rod and secured at 10-cm intervals along the head to aid in estimating fish lengths. A plastic transect reel with 100 m of nylon line, plastic stake, and small compass attached to the wooden handle complete the gear.

The stake is pushed into the sediment to mark the beginning of a transect, and the sampler is pushed across the bottom using the compass to maintain a straight course. Divers record the number of groundfish (three selected species) "kicked out" and estimate their lengths aided by the spaces between the rings mounted on the head. Each diver counts the fish on his side from the handle to end of the head. A fish is counted if the head passes over any portion of the fish or if it is pushed out ahead within sight of the diver. After the 100 m line is payed out, the divers turn and rewind the reel back to the stake. Fish observed on the way back are not counted to avoid bias caused by attraction to the divers or disturbed sediment. For the same reason, if there is discernable water movement on station, the divers swim the down-current leg first. The divers then repeat the procedure in the opposite direction. Data from the two sampling legs (200 m long) are combined, and the total reported as a density per 400 m^2 (200 X 2 m) transect at each station.

In '92, our efforts were directed to work out the technique and train our divers in the procedure. We are also planning in '93 to conduct paired comparisons with the project otter trawl to determine comparability of the two methods of bottom sampling.

IV. RESULTS AND DISCUSSION

B. FISHERIES - LOBSTER

1. Commercial lobster pot-catch fishery

Monitoring the commercial American lobster (*Homarus americanus*) fishery in 1992 in the Pilgrim study area began in May and concluded in October. Lobster catch statistics and biological data (i.e., carapace length - CL, sex, size at maturity) were collected over the six months during 11 sampling trips aboard a commercial lobster boat. Data were obtained on 2,654 lobster taken from 2,096 lobster pot-hauls at various locations within the study area (Figure 3).

Overall catch per pot of legal, CL $\geq$82.6 mm, and sublegal lobster combined from the Pilgrim area was 1.3, while last year's value was 2.3. Twenty-one percent (547) of the total catch were legal lobster for an annual catch rate of 0.25 legals per trap-haul, which is 30% lower than last year's rate of 0.37. The lowest monthly legal catch rate occurred in June (0.16), and the highest in October (0.38) (Figure 4). The annual ratio of sublegal to legal lobster was 3.9:1, compared to 5.2:1 last year.

The legal catch-per-trap-haul rates for the commercial lobster fishery in the Pilgrim vicinity from 1983-1992 are portrayed in Figure 5. Reduced catch rates in 1984 and 1987 are believed to be due to cooler ambient temperatures in those years which depressed or at least delayed the early season lobster molt, which would have affected subsequent recruitment to legal size and lowered lobster activity (Campbell 1983; Estrella 1985; Estrella and Cadrin 1988).

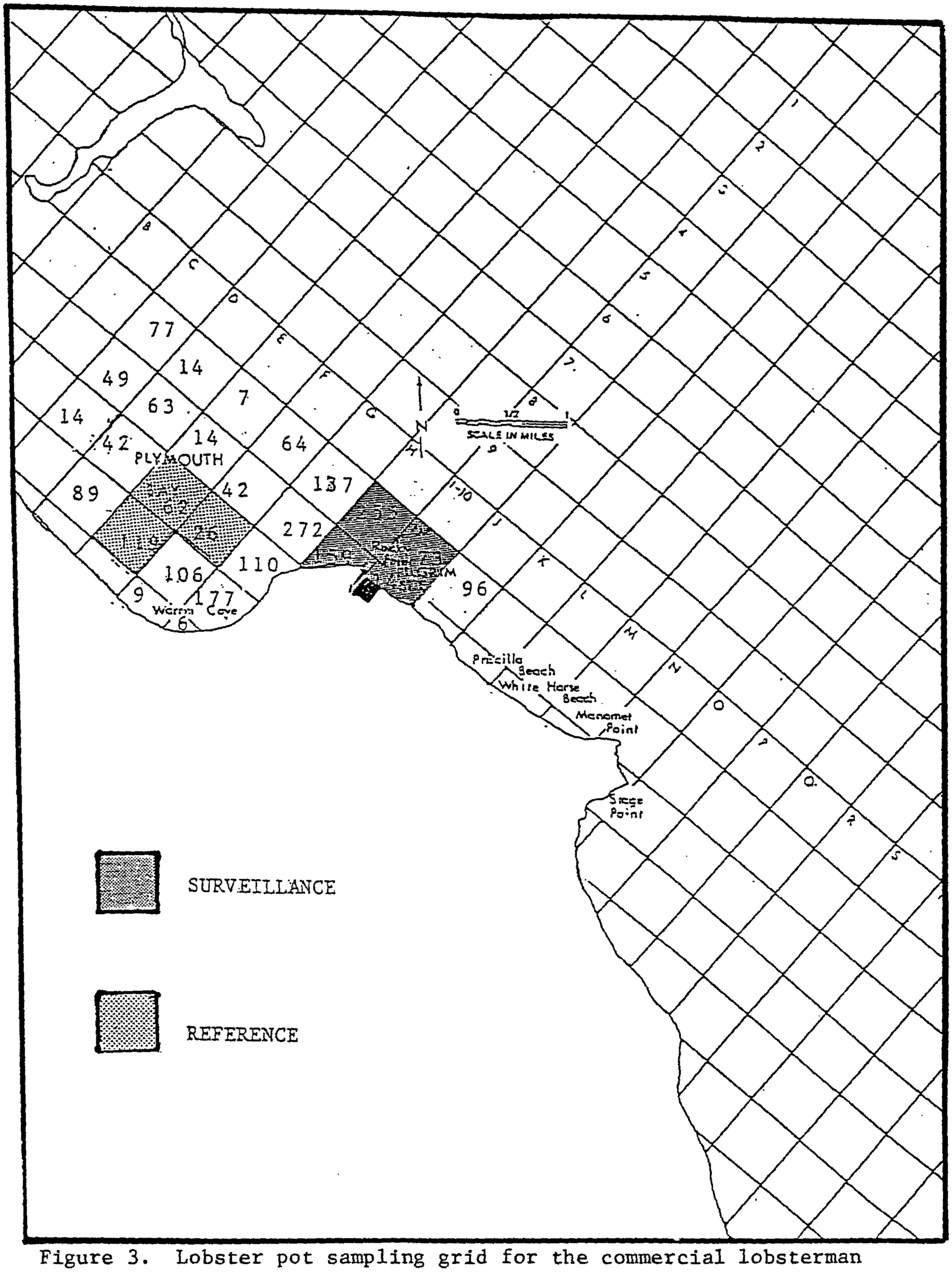

Figure 3. Lobster pot sampling grid for the commercial lobsterman monitored in the Pilgrim Power Plant area [surveillance (H-11, H-12, I-11 and I-12) and reference (E-13, E-14, and F-13) quadrats are shaded] and distribution of his traps sampled in 1992.

Small increases in the regulatory minimum legal size of lobster occurred in both 1988 and 1989, yet legal catch rates increased slightly in these years. The legal catch rate in 1992 was the lowest of the past ten years.

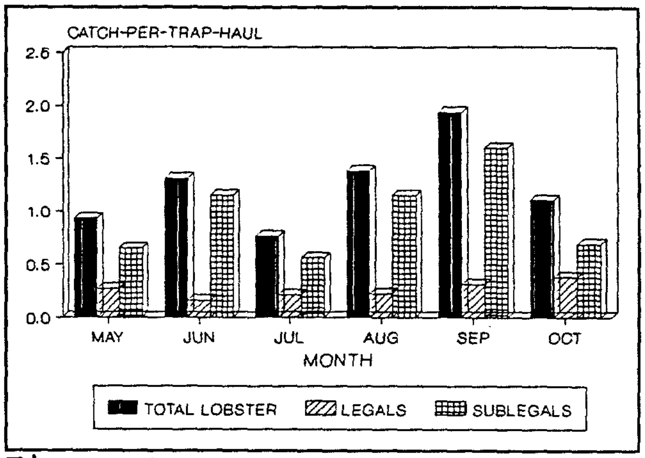

Figure 4. Monthly commercial lobster catch per trap-haul in the Pilgrim Station vicinity, 1992.

Males comprised 47% of the sampled catch. There were 84 ovigerous (egg-bearing) females sampled (5.9% of the female catch), of which 58 (4.0% of all females and 69% of all ovigerous females) were sublegal. The overall percentage of ovigerous females was higher in May (7.9%) and October (13.6%) than in June and July (3.6%). The incidence of egg-bearing females reflects the two-year reproductive cycle of the American lobster (Aiken and Waddy 1982). Sexually mature females generally mate after the summer molt, but it is not until fall of the following year that they extrude their fertilized eggs which are carried externally throughout the winter, hatching from late spring into the summer.

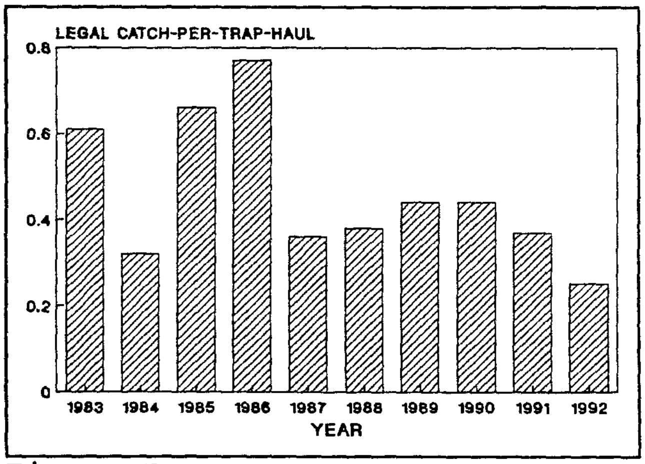

Figure 5. Commercial legal lobster catch rates (catch-per-trap-haul) for western Cape Cod Bay, 1983-1992.

2. <u>Research Lobster Trap Fishing</u>

We trapped lobster from June through September 1992 in the environs of Pilgrim Station. This year was the seventh of our research trap fishing. We completed 57 sampling trips. Eight percent of the lobster catch were of legal-size.

For the past three years, the minimum legal size for lobster retention in Massachusetts has remained at $\geq$ 82.55 mm (3.25 inches) carapace length (CL), after having undergone a management-directed gauge increase in both 1988 and 1989. These changes in legal size were not accompanied by an increase in the size of the escape vent in our sampling traps. This contributed directly to increase our catches of sublegal lobster relative to legals, and is reflected in the annual catch ratio of sublegals to legals, which was 5.8:1 in 1988, 6.6:1 in 1989, 8.1:1 in 1990, 9.0:1 in 1991, and 11.5:1 in 1992.

The number of lobster of all sizes captured over a two-day set ranged from 0 to 12 per trap-haul, with legals ranging from 0 to 4 and sublegals, 0 to 11. In nine percent of the hauled traps, there were no lobster. The overall seasonal (June-September) mean catch-per-trap-haul (CTH) in the study area of lobster (pooled for size and sex) increased from 1.2 in 1986 to 3.7 in 1990/1991 but declined slightly to 3.3 in 1992.

The 1992 study area legal catch rate declined for the third consecutive year (Figure 6). Priscilla Beach has had slightly higher legal catch rates than the other sites for all years except 1988. Annual sublegal catch rates have remained relatively constant in the study area since 1989 (Figure 7). Rocky Point has led in sublegal catch rate amongst areas from 1987-1991.

Monthly catch rates as catch-per-trap-haul-per-set-over day, CTHSOD, of legal and CTH of sublegal lobster in the study area for 1992 are plotted in Figures 8 and 9, respectively. Legal catch rates in each area were lowest in June; our commercial catch data showed a similar June nadir. Priscilla Beach had the highest annual legal CTHSOD of 0.151.

Sublegal catch rates were lowest at all areas in July, a trend also reflected in this year's commercial data, which is likely attributed to a delayed spring molt occurring then. Annual sublegal lobster catch rates were very similar amongst the three sites.

Males slightly outnumbered

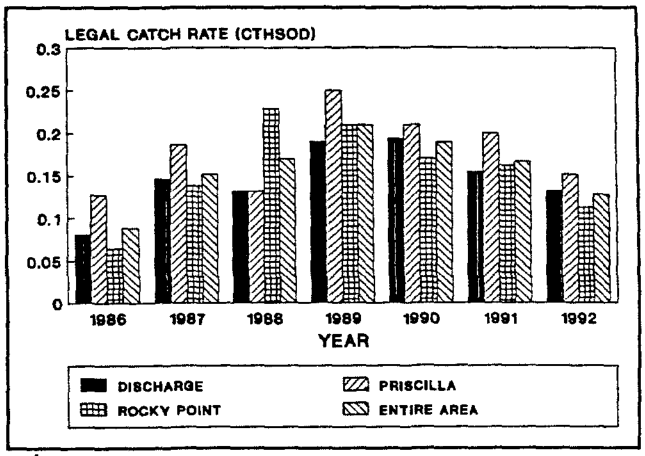

Figure 6. Legal lobster catch rates (CTHSOD) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1986-1992.

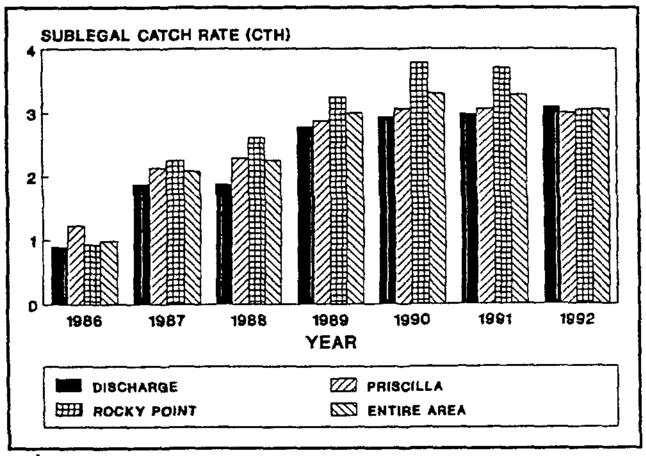

Figure 7. Sublegal lobster catch rates (CTH) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1986-1992.

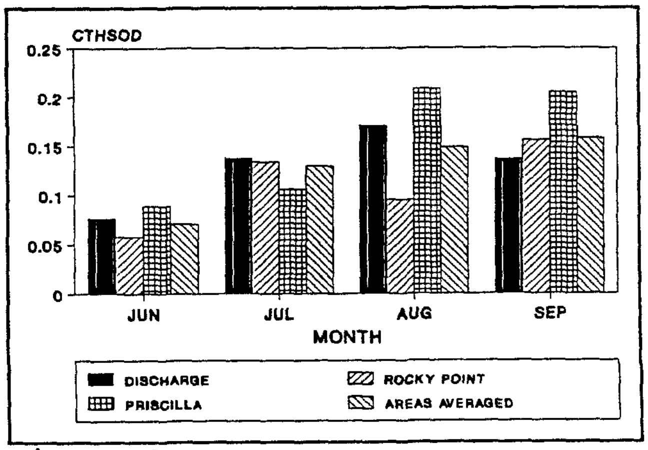

Figure 8. Monthly legal lobster catch rates (CTHSOD) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1992.

females in research trap catches, comprising 52% of the total. Conversely, females have typically outnumbered males in past commercial catches made in the slightly deeper waters of western Cape Cod Bay (Kelly et al. 1987; Lawton et al. 1990). Again this year, more females (53%) were caught in the commercial catch. A preponderance of males in shoal-water pot-catches also was reported by Briggs and Muschacke (1979) in Long Island Sound.

There were 38 egg-bearing (ovigerous) females sampled which represents 1.7% of the research catch of females; 24 (63%) of these ovigerous females were sublegal. The percent of females ovigerous was 1.5% in last year's research catch. In the inshore commercial lobster catch data from western Cape Cod Bay, this percentage was 5.9% in 1992. The commercial traps are fished in deeper waters, where the percent of females carrying eggs can be substantial in late spring and early fall (see previous section).

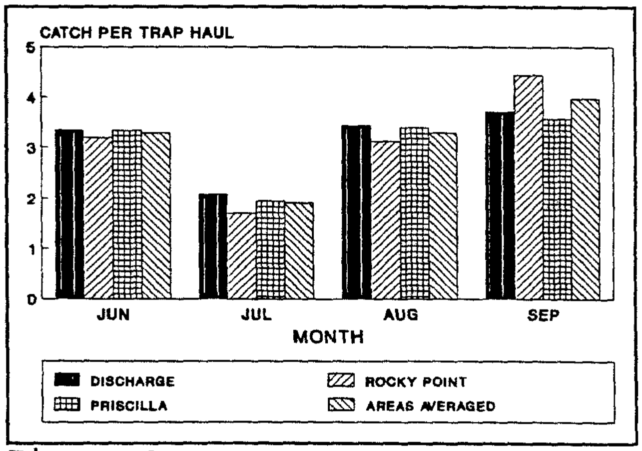

Figure 9. Monthly sublegal lobster catch rates (CTH) by area from research lobster gear fished in the vicinity of Pilgrim Station, 1992.

Culls (lobster with missing and/or regenerating claw(s)) captured during research fishing comprised 29% of the catch for the second consecutive year. A 28% cull rate in 1990 was slightly higher than that for 1989 (27%) and for 1988 (23%). In general, the cull rate obtained by sampling commercial catches has increased in the Pilgrim area during the past decade, concomitant with an expansion in commercial and recreational lobstering efforts.

Each lobster trap employed in this study contains a rectangular escape vent (44.5 mm x 152.4 mm) and is designed to retain legal-sized lobster; however, sublegals also are captured. The size range (CL) of lobster sampled in 1992 was 41 mm to 120 mm. The overall mean size was 74.9 mm, which is only 0.5 mm smaller than the average for 1991. Sublegals averaged 73.9 mm CL, and legals, 86.7 mm CL.

Size distributions were plotted for 1992 (Figure 10) and for the past four years (1989-1992) during which time the minimum legal size has remained constant (Figure 11). The length-frequency histograms display effects of lobster availability, trap vulnerability, and fishing mortality. The overall stepwise increase in catches between 50 and 81 mm CL suggests that lobster become increasingly vulnerable to retention in the traps, with the mode at the pre-recruit size of 79 mm CL. Reduced catches of lobster of a smaller size are related to gear design, i.e., vent escapement. The lower catches of lobster at legal size and larger reflect the high fishing mortality from intensive commercial and recreational lobster fisheries in the Pilgrim area.

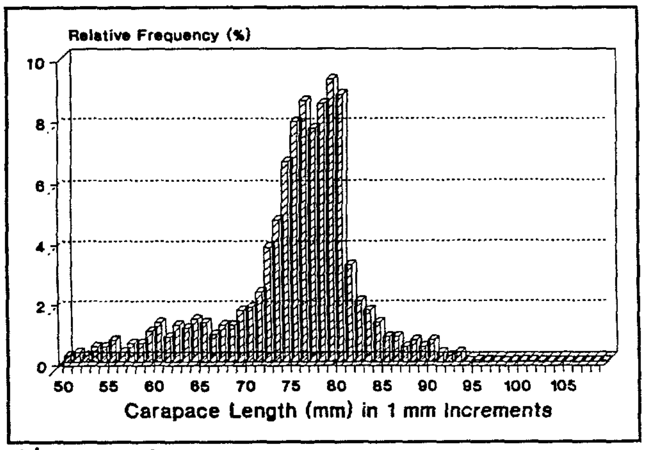

Figure 10. Size distribution of lobster captured in the research trap study off Pilgrim Station in 1992.

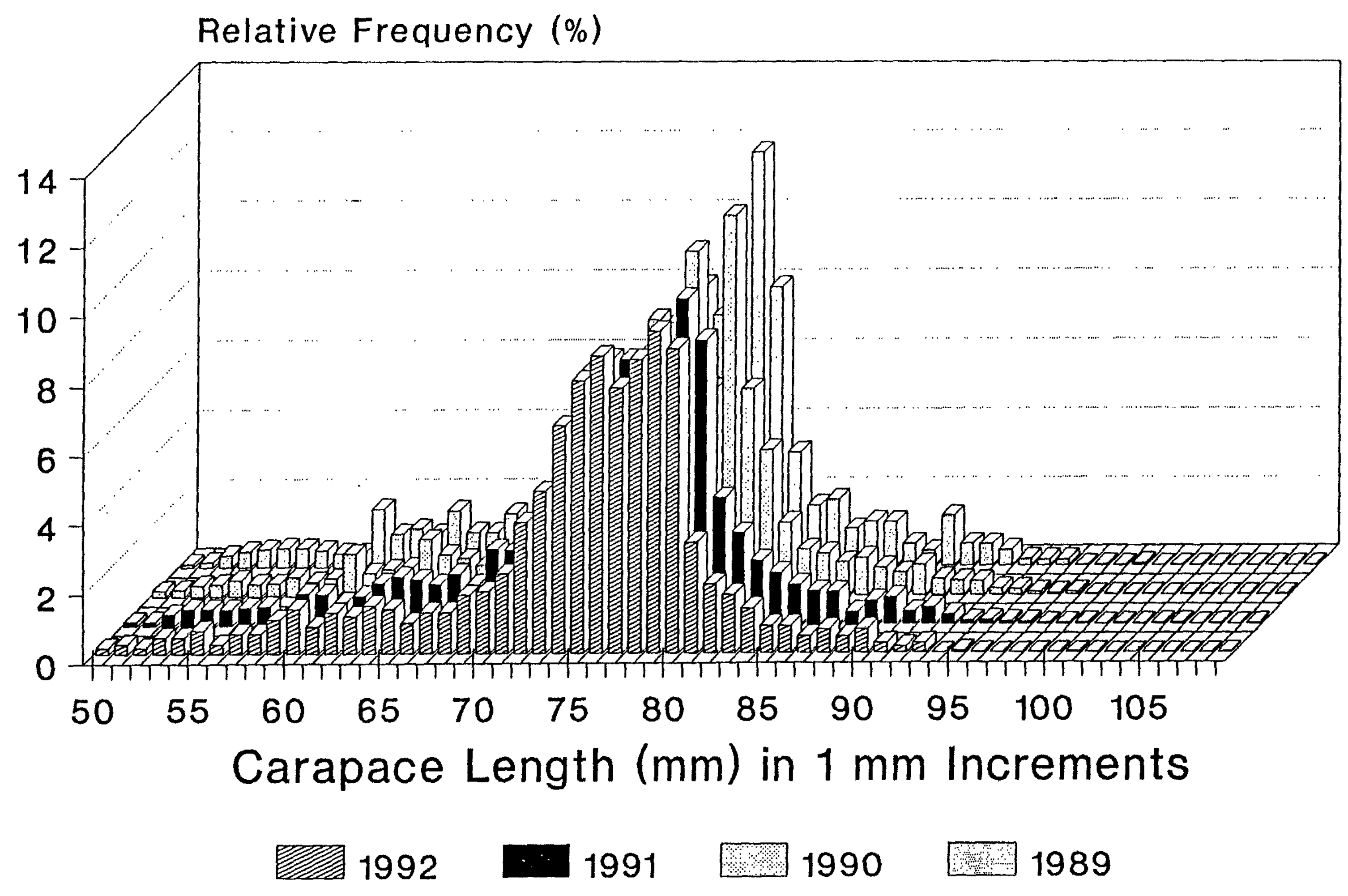

Figure 11. Size distribution of lobster captured in the research trap study off Pilgrim Station from 1989 to 1992.

B. FISHERIES - FINFISH

A species check list of fish observed or collected by all gear types in the Pilgrim area in 1992, complete with scientific names (Robins et al. 1991), is found in Table 1.

Table 1. *Taxonomic checklist of finfish species (classification according to Robins et al. 1991) collected or observed in waters adjacent to the Pilgrim Nuclear Power Station in 1992.*

Class: Elasmobranchiomorphi
- Order: Squaliformes
  - Family: Squalidae - dogfish sharks
    - *Squalus acanthias* Linnaeus - spiny dogfish
- Order: Rajiformes
  - Family: Rajidae - skates
    - *Raja erinacea* (Mitchill) - little skate
    - *Raja radiata* (Donovan) - Thorny skate

Class: Osteichthyes
- Order: Clupeiformes
  - Family: Clupeidae - herrings
    - *Alosa aestivalis* (Mitchill) - blueback herring
    - *Alosa mediocris* (Mitchill) - hickory shad
    - *Alosa psuedoharengus* (Wilson) - alewife
    - *Clupea harengus* Linnaeus - Atlantic herring
    - *Brevoortia tyrannus* (Latrobe) - Atlantic menhaden
- Order: Salmoniformes
  - Family: Osmeridae - smelts
    - *Osmerus mordax* (Mitchill) - rainbow smelt
- Order: Gadiformes
  - Family: Gadidae - codfishes
    - *Gadus morhua* Linnaeus - Atlantic cod
    - *Urophycis tenuis* (Mitchill) - white hake
    - *Urophycis chuss* (Walbaum) - red hake
    - *Merluccius bilinearis* (Mitchill) - silver hake
    - *Pollachius virens* (Linnaeus) - pollock
- Order: Atheriniformes
  - Family: Atherinidae - silversides
    - *Menidia menidia* (Linnaeus) - Atlantic silverside
- Order: Gasterosteiformes
  - Family: Syngnathidae - pipefishes and seahorses
    - *Syngnathus fuscus* Storer - northern pipefish
- Order Scorpaeniformes
  - Family: Triglidae - searobins
    - *Prionotus carolinus* (Linnaeus) - nothern searobin
    - *Prionotus evolans* (Linnaeus) - striped searobin
  - Family: Cottidae - sculpins
    - *Hemitripterus americanus* (Gmelin) - sea raven
    - *Myoxocephalus aenaeus* (Mitchill) - grubby
    - *Myoxocephalus octodecemspinosus* (Mitchill) - longhorn
    - *Myoxocephalus scorpius* (Linnaeus) - shorthorn sculpin

Table 1 (continued),

Family: Cyclopteridae - lumpfishes and snailfishes
Cyclopterus lumpus Linnaeus - lumpfish

Order: Perciformes
Family: Percichthyidae - temperate basses
Morone saxatilis (Walbaum) - striped bass

Family: Pomatomidae - bluefishes
Pomatomus saltatrix (Linnaeus) - bluefish

Family: Sparidae - porgies
Stenotomus chrysops (Linnaeus) - scup

Family: Labridae - wrasses
Tautoga onitis (Linnaeus) - tautog
Tautogolabrus adspersus (Walbaum) - cunner

Family: Pholidae - gunnels
Pholis gunnellus (Linnaeus) - rock gunnel

Family: Scombridae - mackerels
Scomber scombrus Linnaeus - Atlantic mackerel

Family: Stromateidae - butterfishes
Peprilus triacanthus (Peck) - butterfish

Order: Pleuronectiformes
Family: Bothidae - lefteye flounders
Paralichthys dentatus (Linneaus) - summer flounder
Paralichthys oblongus (Mitchill) - fourspot flounder
Scophthalmus aquosus (Mitchill) - windowpane
Etropus Microstomus (Gill) - smallmouth flounder

Family: Pleuronectidae - righteye flounders
Pleuronectes ferrugineus (Storer) - yellowtail flounder
Pleuronectes americanus Walbaum - winter flounder

1. <u>Groundfish - Bottom Trawling</u>

With a 10-year (1982-1991) time series of standardized near-shore trawl survey data in hand, during which time repairs had been made to the gear, we came to believe this winter that the efficiency of the Wilcox trawl had been compromised because of wear. We purchased from the same net company a new trawl purported to be comparable to the old one and implemented its use in the study area in the spring of 1992. After collecting three seasons of data, it appears that the performance of the two nets is different. We are obliged to conduct paired fishing power trials in 1993 to compare gear efficiency of the old and new trawls. Until this is done, we will use 1992 trawl data for inter-year comparisons with discretion. In this report, intra-year comparisons will be stressed with 1992 data.

The bottom trawl catch from 81 tows completed at 4 fixed stations (see Figure 2 in Section II (Introduction) of Semi-Annual Report No. 41) in the Pilgrim Study area in 1992 totaled 2,526 fish, representing 28 species (Table 2). Three groundfish - little skate, winter flounder, and windowpane - predominated, comprising 85.6% of the total. Over the year, the greatest number of species (21) was collected at Station 1 in Warren Cove.

Catches in number of fish were highest at Station 3 which transects the thermal plume. It was in the discharge area that catch per unit effort, i.e., catch per tow, was highest for the three dominant groundfish and for pooled species (Table 3). Catch

Table 2. Expanded bottom trawl catch[1], totals, and percent composition of groundfish captured at fixed stations in the Pilgrim Power Plant area, January to December, 1992.

Species	1 Warren Cove	3 Pilgrim Discharge	4 Priscilla Beach	6 Pilgrim Intake	Totals	Percent of total catch
Little skate	268.4	379.2	319.7	136.5	1,103.8	43.7
Winter flounder	181.1	199.1	123.9	93.7	597.8	23.7
Windowpane	150.4	170.3	103.4	35.8	459.9	18.2
White hake	7.9	35.0	34.1	23.4	100.4	4.0
Yellowtail flounder	4.0	55.5	17.4	15.4	92.3	4.0
Scup	22.8	14.2	0.0	0.0	37.0	1.5
Atlantic cod	16.0	5.7	5.4	1.1	28.2	1.1
Rock gunnel	8.5	1.2	2.1	1.5	13.3	0.5
Northern pipefish	10.8	1.1	0.0	0.0	11.9	0.5
Longhorn sculpin	6.0	2.2	1.0	2.6	11.8	0.5
Other species[2]	33.9	15.7	11.2	8.5	69.3	2.7
Total fish	709.8	879.2	618.2	318.5	2525.7	
Number of tows	23	20	26	12	81	
Catch per tow	30.9	44.0	23.8	26.5	31.2	
Percent of catch	28.1	34.8	24.5	12.6		
Number of species	21	16	14	13	28	

[1]Catch rates were expanded for tows less than the standard 15-minute duration.
[2]Represents pooled totals from 18 other species of low catch abundance.
Shaded columns are data from surveillance stations.

Table 3. Bottom trawl catch data[1] for dominant groundfish in the vicinity of Pilgrim Station, January to December, 1992.

Station	Winter flounder	Little skate	Windowpane
1			
Mean catch per tow	7.9	11.7	6.5
Mean size (cm)	27	38	22
Size range (cm)	8-43	15-56	8-47
3			
Mean catch per tow	10.0	19.0	8.5
Mean size (cm)	25	35	22
Size range (cm)	3-43	15-55	7-33
4			
Mean catch per tow	4.8	12.3	4.0
Mean size (cm)	23	35	22
Size range (cm)	5-41	19-55	6-30
6			
Mean catch per tow	7.8	11.4	3.0
Mean size (cm)	23	39	23
Size range (cm)	7-40	23-52	9-32

[1]Catch rates were expanded for tows less than the standard 15-minute duration.
Shaded rows are data collected at surveillance stations.

rates for winter flounder and little skate were remarkably similar at Station 1 and at Station 6 (Intake).

Little skate

Little skate comprised almost 44% of the trawl catch in 1992. The annual mean catch per tow for pooled stations was 13.6. The highest annual station catch rate (19.0) was obtained in the Discharge area (Table 3). Relative abundance of skates at the other three stations was similar, ranging from 11.4 to 12.3 fish per tow. Catch rates mirrored those found in the study area in 1983, 1984, and 1985.

Winter Flounder

Winter flounder ranked second in the trawl catch (24% - all stations pooled). Relative abundance was highest in the Discharge area and lowest at Station 4 off Priscilla Beach (Table 3). Recently, the overall abundance of winter flounder has declined in the Gulf of Maine (Northeast Fisheries Center 1991), including

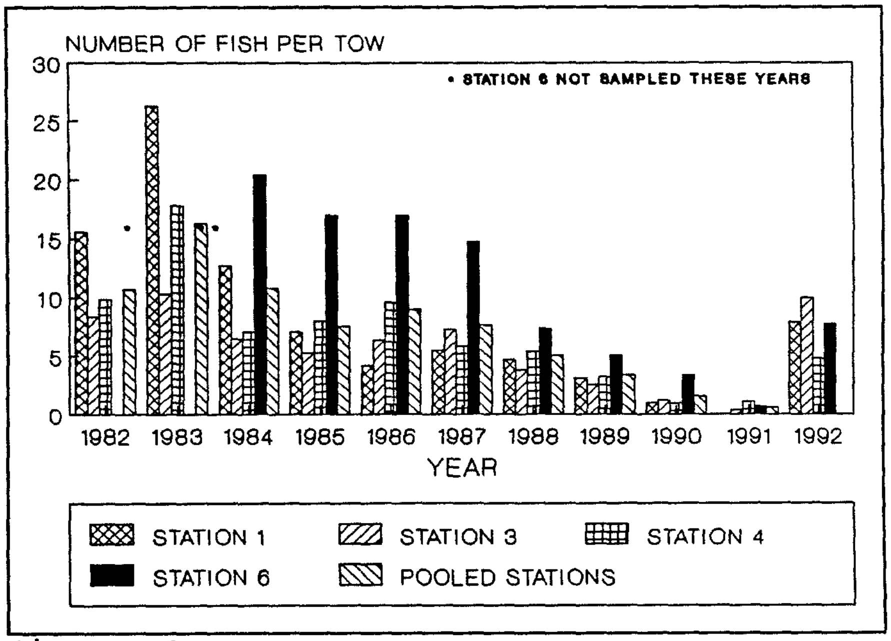

Figure 12. Mean annual catch per tow (number) of winter flounder at four stations and all stations pooled in the Pilgrim Station area, 1982-1992.

the inshore sector of western Cape Cod Bay (Figure 12).

Flounder catches were highest in the study area in the spring (April-June), followed by the summer season; winter catches were especially low. The seasonal catch rates were 0.2, 10.5, 8.9, and 6.4 for winter - fall, respectively. Adults disperse from the winter estuarine spawning grounds in Plymouth-Kingston-Duxbury Bay into deeper waters within the inshore sector of western Cape Cod Bay during spring and summer (Howe and Coates 1975), and become available to our gear.

The total lengths of flounder captured ranged from 3 to 43 cm, which includes ages 0+ to 9+ fish. The mode in length frequencies was 28 cm, with most flounder being 3-4 years old. There was little variation in size of flounder caught at the different stations (Table 3).

Windowpane

Windowpane ranked third in our trawl catch at 18% of the total for the study area. The annual mean catch rate for pooled sampling stations was 5.7 and ranged from 3.0 to 8.5 for individual stations. Seasonally, the catch rate was highest during the summer (July-September) at 8.5; none were taken in winter. The mean size of windowpane was nearly identical at each station.

Other Groundfish

Comprising almost 15% of the trawl catch, the remaining 25 finfish species were captured in far lower numbers (Table 2). The overall catch rate for this group in the study area was 4.5 fish.

2. Groundfish - Diving Transects

In 1992, we initiated diver surveys along transects established at three of our fixed trawl stations - Discharge, Intake, and Priscilla Beach; Warren Cove was not included in order to concentrate on the power plant impact areas. This technique was selected to refine our sampling of the groundfish dominant in the Pilgrim Station area. Diver sampling is not limited by bottom topography or the presence of fixed gear, and we believe sampling variability will be reduced by employing direct counts of fish instead of relying on a sample catch from a net. We are focusing on winter flounder, windowpane, and little skate - three species that have numerically dominated our trawl catches. For each, the variables of interest are relative abundance, size, and distribution.

Our efforts in 1992 were directed primarily at refining techniques *in situ* and training our divers in the procedure. Proficiency at enumeration and size estimation of fish underwater are critical to ensure accuracy of the data, necessitating the use of trained personnel.

The maneuverability of the divers and the sampler permitted passage over lobster pots, buoy and trawl lines, and boulders. The divers were able to move the sampler through the macroalgae and organic debris deposited on the bottom of the Intake embayment, although occasional stops were needed to clear the sampler head. At mid- to high tide, it was possible to sample in the discharge area up as far as the large boulder located 60 m out from the discharge canal (Observational dive station D_1). However, the velocity of the discharge prevented us from penetrating any closer to shore.

A summary of the sampling data is found in Table 4. We were able to sample the stations seven times and found that the divers were able to accurately identify and enumerate fish, even very small (< 5 cm) ones hiding in the detritus in the Intake.

Table 4. Number of fish, number per square meter, and size range of three fish species observed by divers along transects at three trawl stations in the immediate vicinity of Pilgrim Station, June-October, 1992.

Station	Winter flounder	Little skate	Windowpane
Discharge			
Number	19	1	4
Number per m^2 sampled	0.01	0.0004	0.001
Size range (cm)	3-40	48	10-26
Intake			
Number	148	10	4
Number per m^2 sampled	0.06	0.004	0.002
Size range (cm)	2-37	10-45	6-25
Priscilla Beach			
Number	2	9	-
Number per m^2 sampled	0.001	0.004	
Size range (cm)	4	12-50	
Total			
Number	169	20	8
Number per m^2 sampled	0.02	0.003	0.001
Size range (cm)	2-40	10-50	6-26

Shaded rows are data collected at surveillance stations.

Winter flounder accounted for the majority of fish recorded (86%), being particularly abundant in the Intake embayment (Table 4). However, given the limited amount of sampling, we feel it premature to make comparisons between stations and species. We do not yet know if the three species observed are equally vulnerable to this technique and at what size. Some bias may be imparted by the behavior of the species. From our trawl and haul seine surveys we know that winter flounder tend to aggregate in the Intake, particularly juveniles. This has not been documented for the other two species.

At this time, comparison with project trawl catches is also inappropriate. We have not yet been able to conduct a comparability study between the two sampling techniques. However, there is a usefulness to diver transects, in that we were able to sample in the Intake during late spring and summer, when the proliferation of lobster gear prevented trawling there.

Having instituted the diver technique in 1993, we will give high priority to making paired comparisons with the project otter trawl to determine their comparability and will continue to survey the transects sampled in 1992.

2. Pelagic and Benthi-Pelagic Fishes

Monthly gill-net catches in 1992 yielded 22 finfish species numbering 439 fish. The top 10 species are listed in Table 5. Gill-net sampling was reduced to one overnight set per month to decrease sampling mortality. No sets were made in February, March and November because scheduled sampling events were thwarted by inclement weather.

The annual mean catch rate (catch per standard set) for pooled species by gill net (5 panels of 3.8 - 8.9 cm mesh) decreased to an all time low of 39.6 fish per set; last year's value was 82.3 (Figure 13). The catch rate has been relatively low the last four years. Catches of pollock, Atlantic herring and cunner, the three

Table 5. Catch in number and percent composition of the top 10 fish species sampled by gill net (7 panels of 3.8-15.2 cm mesh) in the immediate vicinity of Pilgrim Station, January-December 1992.

	Species	Number	Percent of Total Catch
1.	Pollock	176	40.1
2.	Striped bass	77	17.5
3.	Cunner	40	9.1
4.	Atlantic herring	34	7.7
5.	Tautog	33	7.5
6.	Scup	14	3.2
7.	Alewife	8	1.8
8.	Atlantic cod	7	1.6
9.	Sea raven	7	1.6
10.	Longhorn sculpin	6	1.4
	Total	402	91.5

species that have dominated gill-net catches since 1971, decreased from last year, contributing to the lower overall catch rate.

Of the gill-net catch, (7 panels of 3.8 - 15.2 cm mesh), pollock ranked first at 40.1% of the catch, striped bass second at 17.5% and cunner third at 9.1%. Atlantic herring fell to fourth in the hierarchy with 7.7% of the catch. Striped bass replaced Atlantic herring, which traditionally has ranked second in the percentage of catch.

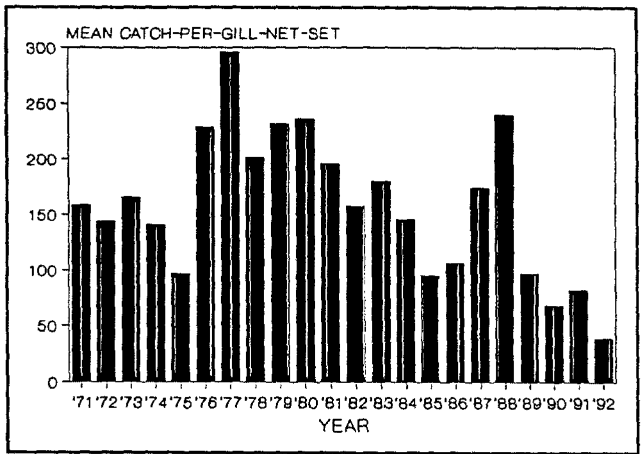

Figure 13. Index of relative abundance (CPUE) for pooled finfish species captured near Pilgrim Station based on 5 panels of 3.8-8.9 cm mesh, 1971-1992.

Pollock

Pollock were caught from May through October, with the highest monthly catch occurring in May (55% of the total). The five-panel catch rate for pollock decreased in 1992 to its lowest level at 18 fish per set (Figure 14). The pollock catch for the last three years has been at a depressed level relative to the entire 1971-1992 time series. The relative abundance of pollock has fluctuated greatly from the low in 1992 to a high of 140 fish per set in 1980.

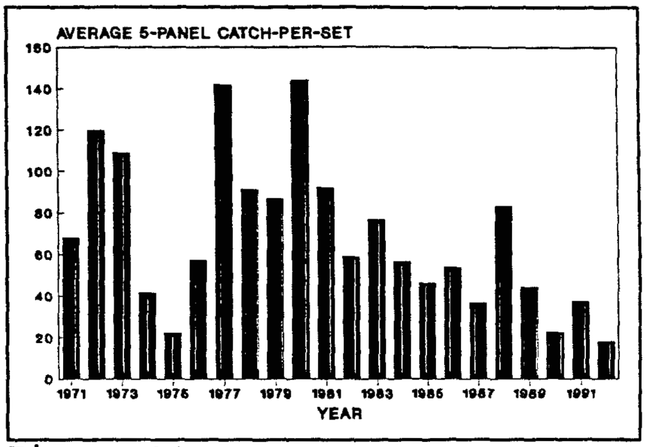

Figure 14. Index of relative abundance (CPUE) for pollock captured near Pilgrim Station based on 5 panels of 3.8-8.9 cm mesh, 1971-1992.

Striped Bass

Striped bass was the only species that substantially increased in catch from last year. The majority (60%) of striped bass were caught in October this year. Overall, their catches have fluctuated as much as any other schooling species captured by the gill net.

Catch rates in the Pilgrim area were at their lowest in 1977 and 1984; a high was reached in 1990 (Figure 15). For the last three years, the catch rates of striped bass have been relatively high for the time series.

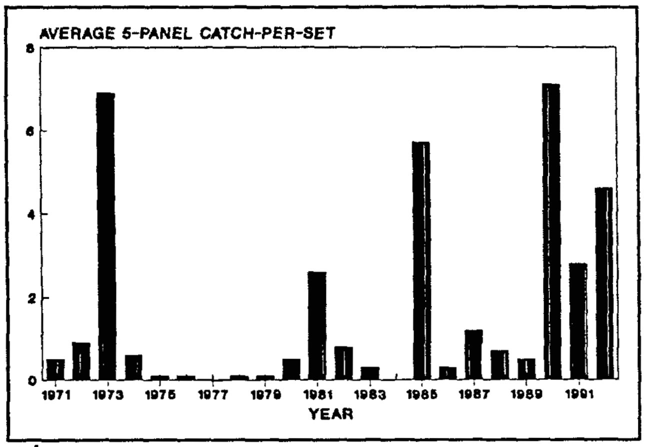

Figure 15. Index of relative abundance (CPUE) for striped bass captured near Pilgrim Station based on 5 panels of 3.8-8.9 cm mesh, 1971-1992.

Striped bass, because of their size, have a greater tendency of being captured in the larger mesh sizes of the gill net. Our present net has seven panels, which include two larger meshes (11.4 and 15.2 cm). Seventy-seven striped bass were caught in total, whereas 41 bass were caught in the five smaller mesh panels.

Cunner

Cunner were caught from May through September. The relative abundance of cunner in the Pilgrim area has been low since 1985, with this year's catch rate being the second lowest (4.3 fish per set) of the 21-year time series (Figure 16).

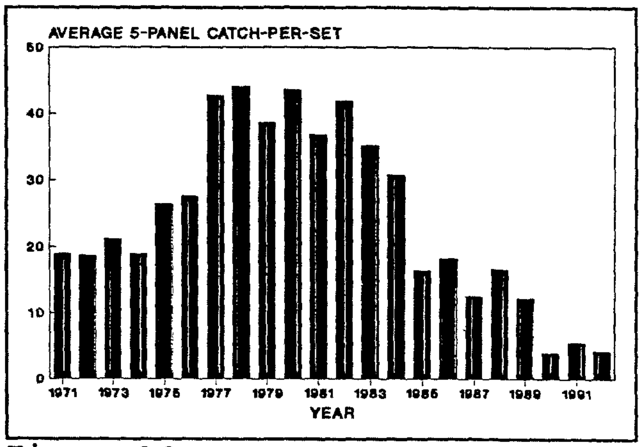

Figure 16. Index of relative abundance (CPUE) for cunner captured near Pilgrim Station based on 5 panels of 3.8-8.9 cm mesh, 1971-1992.

The lowest catch rate was recorded in 1990 with 4.0 fish per set. Cunner catches have been decreasing overall since 1980, with the last three years characterized by the lowest catches ever in the time series.

Other Species

Atlantic herring, bluefish, silver hake and tautog catches decreased substantially from last year. No bluefish or silver hake were gill netted in 1992. The tautog catch rate decreased to its lowest level since 1980 (Figure 17).

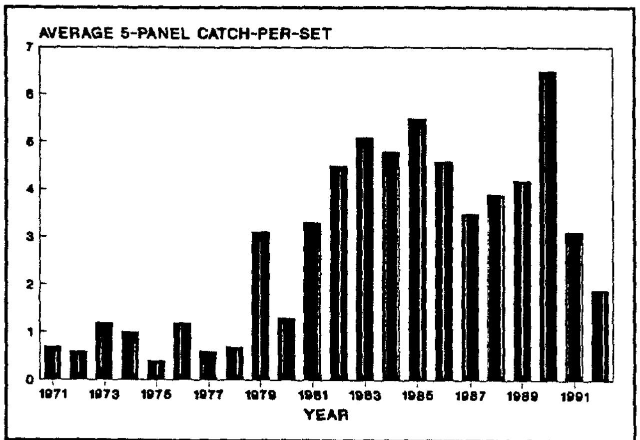

Figure 17. Index of relative abundance (CPUE) for tautog captured near Pilgrim Station based on 5 panels of 3.8-8.9 cm mesh, 1971-1992.

Power Plant Impact

Striped bass and bluefish have a high affinity for the thermal effluent current at Pilgrim Station (Lawton et al. 1987). Their numbers (reflected in our gill-net abundance indices) are generally low in the Pilgrim area when the power plant is not operating. Pilgrim Station increased its annual operational capacity and thermal output from 58% in 1991 to 81% in 1992. The gill-net catch rate doubled, increasing from 4.3 to 8.6 fish per set for striped bass but fell from 4.6 to zero for bluefish. Striped bass abundance is up along the coast, while bluefish catches are dropping (NEFC 1992). Our bluefish catches most likely reflect the declining abundance.

4. Underwater Finfish Observations

Observational diving began in early May, with a total of 10 SCUBA dives made through mid-October. Over 600 fish, comprising 8 species (Table 6), were observed at six fixed sampling stations off the discharge canal (See Figure 2 in Section II (Introduction) of Semi-Annual Report #41). Invertebrates noted included the blue mussel (*Mytilus edulis*), lobster, starfish (*Asterias spp.*), and rock crab (*Cancer irroratus*).

Table 6. Numbers, percent composition, and location of greatest abundance of finfish sighted during underwater observations, May to October, 1992.

Species	Number observed by divers	Percent of total	Station where most abundant
Cunner	290	45.9	C_1
Striped bass	160	25.4	D_2
Tautog	149	23.6	D_2
Bluefish	26	4.1	D_2
Other*	6	1.0	
Total 8 species	631		

* Winter flounder, Grubby, Rock gunnel, and Spiny dogfish

Estimates of lateral visibility (obtained with a diver-held secchi disk and metered line) ranged from 3-9 m (average 5 m), depending on sea condition and incident light.

The number of fish recorded in 1992 was 67% lower than the number in 1991 (1915 fish). This marked decline was primarily due to decreased sightings of cunner (290 in 1992 vs 1219 in 1991). Striped bass and bluefish also were sighted in lower numbers in 1992. A plot of pooled fish-sighted-per-dive (an index of relative abundance) from 1981 through 1992 is found in Figure 18. In 1992, project divers reported an average of 63 fish-per-dive, down 57% from 1991 (147 fish per dive) and the second lowest index of the study. As has been the pattern since 1985 (Figure 18), more fish were observed in the denuded area (65%) than in the control (29%) or stunted (6%) areas.

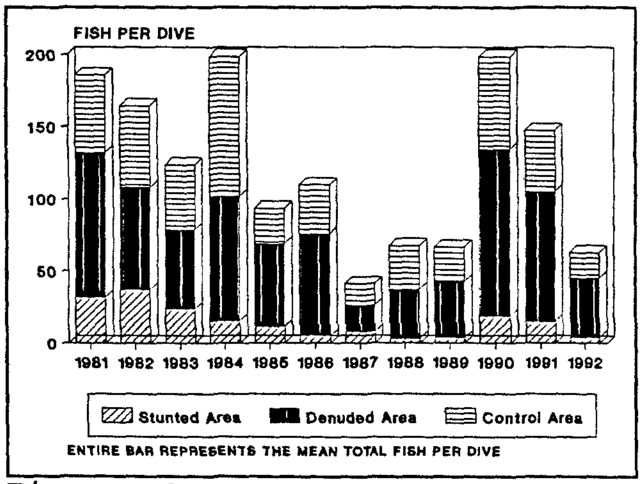

Figure 18. Index of relative abundance (fish-per-dive) for all species (pooled) observed by divers at Pilgrim Station, 1981-1992.

<u>Cunner</u>

Occurring at all stations, cunner was the finfish species observed in greatest numbers by project divers, comprising 46% of all sightings (Table 6). Cunner were found most often in the control area (62%), followed by the denuded (26%) and stunted (12%) areas . The cunner-per-dive index was 29, markedly lower than the 94 fish-per-dive noted in 1991 (Figure 19). The 1992 index is the lowest of the entire 12-year survey.

Examination of individual length estimates made by project divers revealed that fewer small cunner (2-3 cm) were sighted in the study area in 1992 than in 1991.

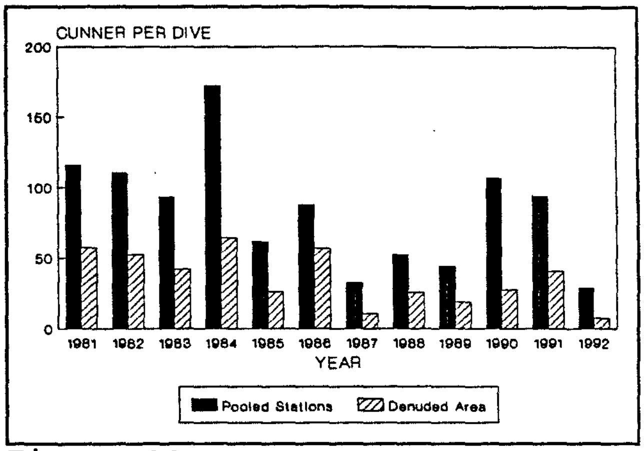

Figure 19. Index of relative abundance (fish per dive) for cunner observed by divers at Pilgrim Station, 1981-1992.

Striped Bass and Bluefish

Striped bass ranked second in diver's observations (Table 6). The fish-per-dive index was 16, which compares well with an index of 19.6 for 1991 (Figure 20). Bluefish ranked fourth in numbers sighted with only 26 recorded. An index of 2.6 bluefish-per-dive was a considerable decrease from the 21 and 15.6 recorded in 1990 and 1991, respectively. This species was not captured in 1992 by gillnet. Bluefish led sportfish catches at the Pilgrim Shorefront in 1992, but this is likely due to directed effort. Exhibiting an affinity for Pilgrim Station's thermal effluent current, the local occurrence and numbers of both species are likely influenced by year-class strength, total mortality (natural and fishing), water temperature, and the abundance of prey in the

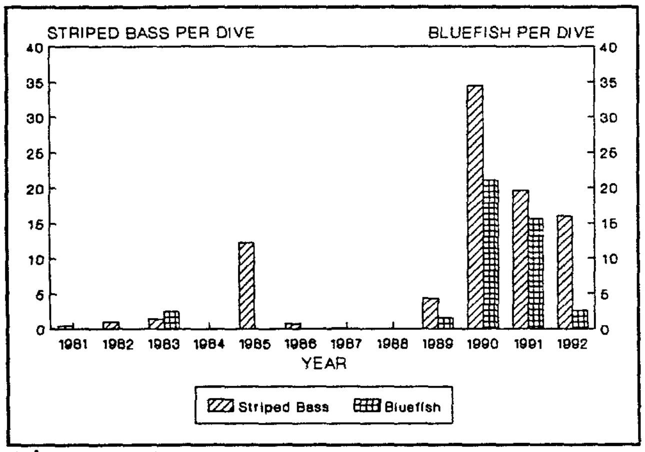

Figure 20. Index of relative abundance (fish-per-dive) for striped bass and bluefish observed by divers at Pilgrim Station, 1981-1992.

area. Commonly angled from the discharge jetties, both species were sighted by divers almost exclusively at Station D_2, inside the mouth of the discharge canal.

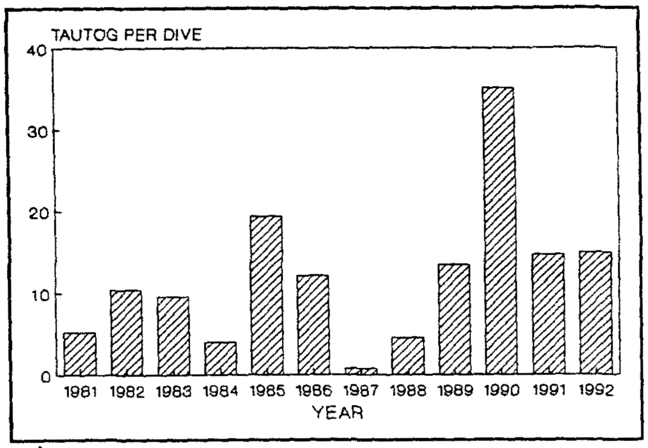

Figure 21. Index of relative abundance (fish-per-dive) for tautog observed by divers at Pilgrim Station, 1981-1992.

Tautog

Ranking third in number sighted (Table 6), tautog generally were found milling about in the mouth of the discharge canal, most commonly on the inside of the southern-most discharge jetty. A comparison of fish-per-dive for this species (Figure 21) in 1992 is on par with that noted in 1991.

5. Sportfishing Survey at Pilgrim Shorefront

The 1992 creel survey began at the Shorefront recreational area at Pilgrim Station on the 18th of April and concluded on the 26th of September. The sampling period entailed 101 days. This general creel survey aims at attaining broad information on trends in time of fishing, effort, species, and catch per unit of fishing effort. Data were collected as time permitted by seasonal public relations personnel from Boston Edison Company, who conducted the survey along with other duties.

There were 2,241 reported angler trips made to the Shorefront during the survey. The sportfish catch totaled 892 finfish, belonging to three species: bluefish, striped bass, and winter flounder. The average number of fish caught per angler trip was

0.4. The daily average number of anglers visiting the Shorefront has increased gradually the last few years (Figures 22 and 23). The mean number of fish caught per angler trip, however, decreased slightly from 0.6 in 1991 to 0.4 in 1992 (Figure 23). There was higher fishing effort but lower catches at the site in 1992 (Figure 22).

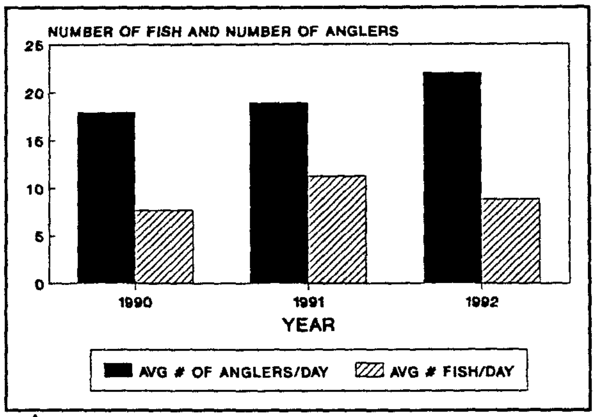

Figure 22. The annual mean number of fish caught per day compared to the average number of anglers per day at Pilgrim Station, 1990-1992.

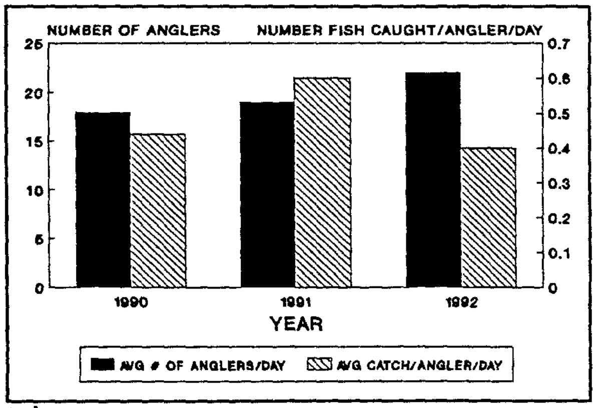

Figure 23. The annual mean number of fish caught per angler per angler trip compared to the average number of anglers per day at Pilgrim Station, 1990-1992.

The average number of anglers visiting the site each day peaked in July, with a mean of 26 (Figure 24). The catch rate was fairly uniform throughout the early and mid-summer, jumping markedly in September to 0.95. This represented a large increase from the rate in August, when there were more angler trips. The large catches of bluefish in September pushed up the overall catch rate.

In 1992, the recreational catch was composed of bluefish (85%), striped bass (12%), and winter flounder (3%). Winter flounder predominated in May (Figure 25), when fishing effort was relatively low. Bluefish dominated the catches in the following months. Striped bass made up a small percent of the monthly catches from June to September. Its highest contribution to monthly catches came in June.

The number of species recorded in the catch decreased this year. Unlike 1991, no cunner, tautog, skate, or pollock were reported.

There were 54 weekdays and 47 weekend days sampled. Substantially less anglers fished at the Shorefront on weekdays as compared to weekends. An average of eight fewer anglers per day fished at the Shorefront on weekdays (Figures 26 and 27). With more anglers at the Shorefront on weekends, more fish were caught (Figure 26), but the overall catch rate per angler was lower than during weekdays (Figure 27). A large number of casual fishermen visited the Shorefront on weekends; their general lack of fishing experience translated into lowering the overall catch rate per angler.

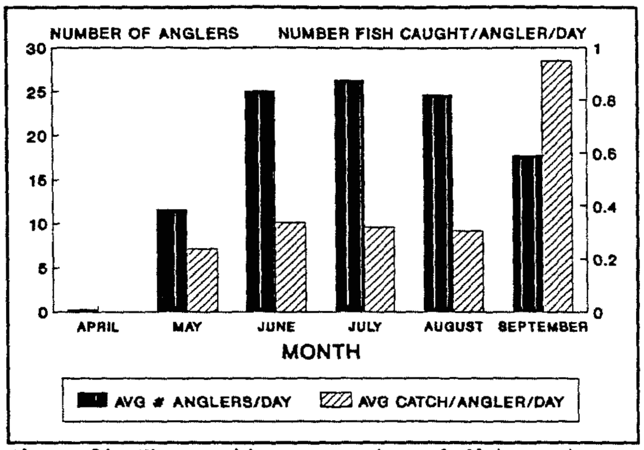

Figure 24. The monthly mean number of fish caught per angler trip compared to the number of anglers at Pilgrim Station, 1992.

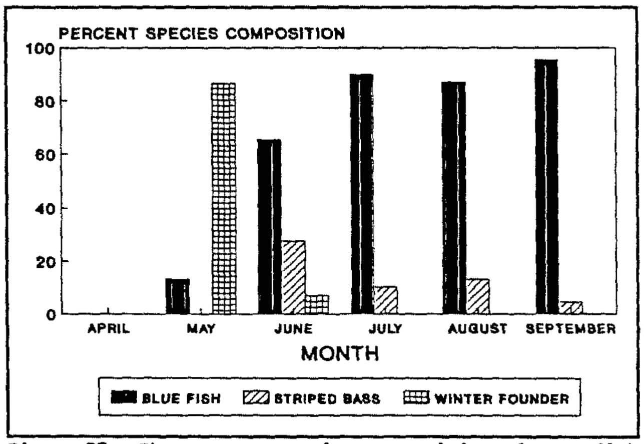

Figure 25. The percent species composition of sportfish catch each month in 1992 at the Pilgrim Shorefront.

Again this year, it is evident that bass and bluefish were attracted to the moving water of the discharge at the power plant.

In early October, we observed numbers of bluefish and striped bass in the thermal plume at Pilgrim Station. Anglers were fishing from the two discharge jetties and boats. No quantitative data are

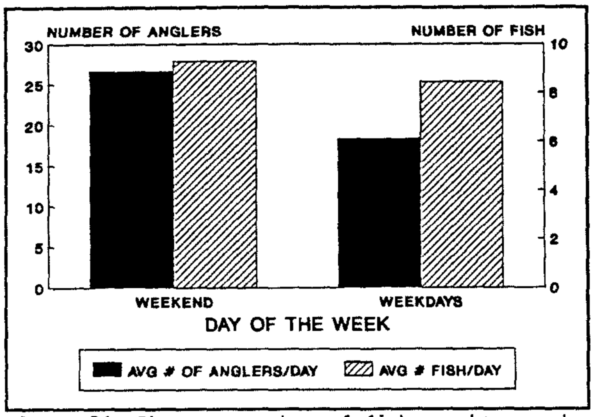

Figure 26. The mean number of fish caught per day and the average number of anglers per day comparing weekends to weekdays at Pilgrim Station, 1992.

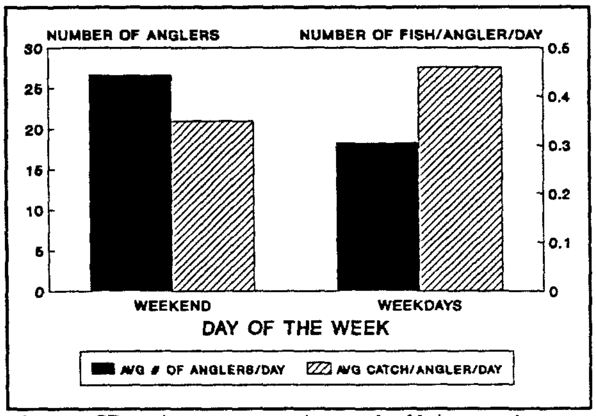

Figure 27. The mean number of fish caught per angler trip and the average number of anglers per day comparing weekends to weekdays at Pilgrim Station, 1992.

available, however, because at this time, the creel survey had been concluded for the year.

6. <u>Cunner: Tagging and Aging</u>

Cunner are temperate water-reef groundfish that are structure-oriented, forming localized populations that have small home ranges. Our mark-recapture data on movements indicate they are rather sedentary at least during the summer off Pilgrim Station. Our tagging objective in 1992 was to estimate the number of cunner in the immediate area of the power plant; these fish would likely be most affected by plant operation. We continued our collaborative aging work with the intent of developing an age-length key.

From July-September 1992, we trapped and measured 1,627 cunner seaward of the outer intake breakwater and discharge. Of these, 665 ($\geq$11 cm total length) were marked with yellow external anchor tags (Figure 2) during seven tagging outings; no sex determinations were made. All fish were released in the area of capture, except for a small sub-sample retained for aging. This allowed for multiple recaptures.

Over the last three years, we have tagged 1,403 cunner off the power plant. Through 1992, 226 (16.0%) marked individuals have been recovered at least once. In 1992 alone, 169 (25.4%) of those tagged that year were recaptured one or more times, 55 (8.3%) in fish pots and 114 (17.1%) sightings during SCUBA surveys. There were at least 10 multiple recaptures, i.e., a marked fish retaken a second time. Also in 1992, we obtained three returns of fish tagged in 1991 and at-large for about one year; they were recovered in the release area.

With external marking of fish, tag retention may be compromised. Some shedding occurred of the tags used in 1992. Because cunner are found in proximity to hard bottom, often residing under rocky outcrops and within crevices, there is the potential for snagging and loss of tags. In 1992 we observed one of our shed tags on the bottom within the release area, four scarred fish apparently a result of tag wounds, and a double-tagged fish that had lost one of its tags.

In traditional finfish mark-recovery programs, the percentage of recaptures typically ranges from 3 to 10% of the marked fish (Matthews and Reavis 1990). Our conventional technique of trapping cunner in fish pots rendered an eight percent tag return in 1992.

When underwater visual recaptures were included, the percentage of returns increased to 25%. By recapturing our own tagged fish, a problem common to many marking programs - namely, a failure to report tag returns - is circumvented.

A successful mark-recapture study necessitates certain assumptions be met. Tagging mortality should be low, with tag retention high. Marked and unmarked fish need to experience the same natural mortality. There should be substantial sampling/fishing over time and space and a high reporting of tagged individuals. It is a requisite that tagged fish randomly intermix with those unmarked (Plate 9 in Volume 2). Both marked and unmarked organisms ought to be equally vulnerable to the fishing and should be captured randomly. Losses through death or emigration are to have the same proportion for both the marked and unmarked. Finally, recruitment, via growth or immigration, to the catchable population should be negligible during the recovery phase.

Of the above, high tag retention and negligible recruitment are somewhat in question. The tag we used in 1990 and 1991 (Figure 2) was tested under controlled conditions and had a short-term tag loss of only seven percent. However, the modified tag of 1992 (Figure 2) had a tag loss of 13% in a controlled mini-experiment. One factor that may offset this is the census period is relatively short: July - October. The Pilgrim study area is an open system, where cunner immigration and emigration of younger life stages is likely, making recruitment estimates difficult. This also confounds the stock identity of the target population. Negligible recruitment is the one condition not often met in many mark-recapture studies, and when it is not, estimates of population size are inflated.

An additional 35 cunner from the Pilgrim area were aged via otoliths in 1992. These fish ranged in total length from 10 to 20 cm. Seven age groups were present, ages 2-8. Cunner that appeared to be young-of-the-year and yearlings were captured or observed by divers in the area but were not part of the aging sample. An age-length key was prepared (Table 7) from those cunner aged the last two years. The 9 and 10 cm cunner were 2-year olds. There was overlap in lengths of cunner amongst age classes because of growth variation in fish of the same age. The age-length key was applied

Table 7. Age-length key for cunner in the Pilgrim area, 1991-1992 (pooled data).

Length (cm)	Age (years)							Total in this length category sampled for age
	2	3	4	5	6	7	8	
9	3							3
10	4							4
11	2	3						5
12	5	5						10
13	1	7						8
14		2	1					3
15			7	3				10
16			4	1				5
17			3	8				11
18			1	2	1	1		5
19				1	1		4	6
20					2		1	3
21					2	2		4
22								0
23						1		1
24						1	3	4
				Total fish aged				82

to ascertain age composition of the tagged group (Table 8). Of the fish tagged, three-year olds predominated, which reflects the youngest age group fully vulnerable to pot-trapping - an influence of gear selectivity.

Table 8. Age composition and size range of cunner captured, marked, and released off Pilgrim Nuclear Power Station for 1991 and 1992 (pooled data).

Age Group	Number of Fish	Percent of total	Range of Total Lengths (cm)
II	194	15	11-13
III	587	45	11-14
IV	344	26	14-18
V	161	12	15-19
VI-VIII	33	2	18-22
Total	1,319		11-22

An estimate of the number of cunner ($\geq$ 11 cm total length), two-years of age and older, found off the power plant in summer was obtained using 1992 trap recovery data with multiple census mark and recapture methods. Cunner (n=665) were marked and added to the population over a period of three months, during which time samples were taken and examined for tagged fish. Samples were replaced except for a small number of unmarked fish kept for aging. We used the following methods to estimate cunner numbers off the outer breakwater: the Schnabel, modified Schnabel, and the Schumacher estimates. The resulting values were: Schnabel = 4,329 cunner; modified Schnabel = 4,242; and Shumacher = 4,976. One drawback to these methods is that they are designed for closed populations. In multiple census estimates, the population is assumed to be constant throughout the census with negligible mortality.

V. HIGHLIGHTS

Lobster - Commercial Fishery

1. Catch statistics and biological data for the commercial lobster fishery in the Pilgrim area were collected from 2,654 lobster sampled from May through October, 1992.
2. Catch per unit effort of total lobster (1.3 CTH) decreased 43% from 1991 (2.3 CTH).
3. Legal catch rate decreased 30% from last year, declining from 0.37 to 0.25 legals per trap-haul.

Lobster - Research Study

1. Fifty-seven sampling days of research pot fishing (June to September, 1992) yielded 4,638 lobster (52% male; 48% female), with legals comprising 8% of the catch.
2. Study area catch rate of legals ($\geq$ 82.6 mm carapace length-CL) declined 25% from 1991, the third consecutive annual decline in the seven-year time series. Study area sublegal (< 82.66 mm CL) catch rate declined by 7% from 1991, after having risen annually since 1986 to a peak in 1990-91.
3. Only 1.7% of the research catch of female lobster were ovigerous (carrying eggs).
4. Carapace lengths of lobster in research catches ranged from 41-120 mm, and averaged 74.9 mm, which is slightly smaller than the mean size from last year.
5. The cull rate remained at 29%, identical to last year's value.

Groundfish - Bottom Trawling

1. Twenty-eight fish species were collected by bottom trawling in the nearshore area of Pilgrim Station.
2. Catches in number of fish were highest at Station 3 which transects the thermal plume.
3. Little skate ranked first at 44% of the total catch. Catch-per-unit-effort (pooled stations) was 13.6 fish per tow.
4. Winter flounder ranked second in catch at 24% of the total. Average catch-per-unit-effort was 6.5 fish per tow.
5. Windowpane ranked third in total catch (18%); overall catch-per-unit-effort was 0.4 fish per tow.

Groundfish - Diving Transects

1. Diving transects were monitored at the Discharge, Intake, and Priscilla Beach trawl stations.
2. The diving survey could be used over substrate inaccessible to the trawl.
3. Winter flounder accounted for the great majority of fish sighted, and were most abundant in the Intake embayment.

Pelagic and Benthi-pelagic Fishes

1. Comprising 22 species, 439 finfish were gill netted during 9 overnight sets.
2. Annual mean CPUE of pooled species (39.6) decreased 48% from 1991.

3. Pollock ranked first, comprising 40% of the catch. Striped bass was second (18%), and cunner, third (9%). Striped bass was the only species that substantially increased in catch from last year.

Underwater Finfish Observations

1. A total of 631 fish, comprising 8 species, was observed during 10 dives in 1992.
2. Total number of fish observed was 67% lower than in 1991, due primarily to decreased sightings of cunner. Observed fish were distributed as follows: 65% in the denuded zone, 29% in the control zone, and 6% in the stunted zone.
3. Cunner was the most common species seen (46% of the total) and was found at all stations. Fewer small cunner were sighted than in 1991, although the proportion of small to large cunner has remained stable the last three years.
4. Fish per dive index for striped bass declined slightly while that for bluefish dropped substantially.
5. The number of tautog sighted in 1992 was similar to that in 1991; this species was found primarily in the discharge area.

Sportfishing Survey

1. Sportfishing was surveyed at the Pilgrim Shorefront from mid-April until late September 1992.

2. A reported 2,241 angler-trips were made by shore-based fishermen to the Shorefront, and about 892 fish, representing 3 species, were caught during the survey.
3. Bluefish comprised 85%, striped bass 12% and winter flounder 3% of the surveyed recreational catch.
4. Effort was up, but the catch rate (0.4 fish caught per angler trip) decreased somewhat from last year.

<u>Cunner Tagging and Aging</u>

1. Collaborative aging work is ongoing to characterize the age-structure of the local cunner population off Pilgrim Station. An age-length key was constructed from the data.
2. The thirty-five fish aged this summer measured 10-20 cm in total length (TL) and were from 7 age groups (2-8).
3. We tagged 84 cunner in 1990, 654 (≥ 11 cm TL) in 1991, and 665 in 1992.
4. In 1992, 169 (25.4%) of those tagged that year were recaptured one or more times. From 1990-1992, 226 (16.0%) marked individuals have been recovered at least once.
5. The number of cunner (≥ 11 cm total length) found during the summer of 1992 off the power plant's outer intake breakwater was estimated with multiple census mark-recapture methods.
6. From recapture data, movement of cunner larger than 10 cm off Pilgrim Station is limited at least during the warmer months of the year.

VI. ACKNOWLEDGEMENTS

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ANNUAL REPORT
ON
MONITORING TO ASSESS IMPACT
OF THE
PILGRIM NUCLEAR POWER STATION
ON THE MARINE FISHERIES RESOURCES
OF WESTERN CAPE COD BAY
(IMPACT ON INDICATOR SPECIES)

Project Report No. 54 (January-December, 1992)
(Volume 2 of 2)

By

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I. EXECUTIVE SUMMARY

The following are the highlights of findings on indicator species selected to assess power plant impact:

Cunner

- There is mounting evidence that cunner in the Pilgrim Station area have substantially regressed in abundance, with gill-net catches, sportfish landings, and diver counts in marked declines.
- Although impingement of cunner at Pilgrim Station was relatively light in 1992, entrainment of their eggs and larvae equated to a loss of 33,800 adults.
- The discharge current shifts the local distribution of cunner by size class in the outfall area.

Winter Flounder

- Pilgrim Station's Intake basin is a mini-nursery ground for winter flounder, which become subject to power plant impingement.
- An estimated 800+ winter flounder - mostly young-of-the-year and yearlings - were impinged in 1992 at Pilgrim Station. Evidently the earlier life stages are less able to escape intake currents.
- There is a small thermal exclusion zone to flounder off the discharge canal during late summer and early fall at the time of highest ambient water temperatures.
- Of more concern is the effect of entrainment. In 1992, 8.4 million flounder larvae were entrained at Pilgrim Station,

which equates to the loss of 20,700 age-three adults from the local population. This conditional mortality may be an unacceptable burden since fishing mortality is presently too high, because the stocks have been overfished.

- Commercial landings and research trawl surveys point to substantially reduced flounder abundance north of Cape Cod.

Lobster

- Entrainment of lobster larvae is not a concern at Pilgrim Station. None were sampled in 1992 at the Station.
- An estimated 783 adolescent phase lobster (21-75 mm carapace length) were impinged at Pilgrim Station in 1992. This would equate to a commercial lobsterman in the area fishing about 20 additional traps during the season.
- We found no significant difference between the reference and surveillance (discharge) areas in commercial legal catch rates for 1983-92.
- We found no relationship between plant operation and legal or sublegal commercial catch rates in the discharge area. Thus, no discharge effect is indicated.
- We found no significant difference in legal and sub-legal catch rates between areas for research lobster data collected in 1992.

II. INTRODUCTION

The Massachusetts Division of Marine Fisheries conducts a field monitoring program to assess impact of Pilgrim Nuclear Power Station (PNPS) on marine fisheries resources in the offsite waters of western Cape Cod Bay. This investigation was funded by Boston Edison Company (Purchase Order No. 69011 in 1992). Focusing on lobster, cunner, and winter flounder in the Pilgrim area, we sampled at surveillance and reference sites employing a variety of gear types to collect data over time. Measurements, counts, percentages, and indices of relative abundance are used in the analyses. These data are summarized in graphs, plots, and tables, and descriptive and inferential statistical procedures are used to test for plant effects.

Volume 2 is an assessment of PNPS impact on three selected indicator species in the Pilgrim area (Table 1). The plates that follow depict various field sampling operations in our investigative program. Included are two plates (7 and 8) of beach seine monitoring which was concluded in 1991 but are presented here for illustrative purposes. A final report on our 11-year seine survey is found under another cover and is the sixth in the Pilgrim Nuclear Power Station Marine Environmental Monitoring Program Report Series.

Table 1. Indicator species assessed for impact of Pilgrim Nuclear Power Station.*

Species	Background History	Basis for Selection as an Indicator Species	Possible Sources of Impact	Sampling Methods
American lobster	RIS	d,r,c,s	I,E,T/C	intake screens/trap/trawl/diving/gill net
Cunner	RIS	d,r,s	I,E,T/C	intake screens/diving/gill net/sportfish catch
Winter flounder	RIS	d,r,c,s	I,E,T/C	intake screens/trawl/diving/sportfish catch/gill net

RIS - representative species selected in the original 316 (a and b) Demonstration Document and Supplement to assess Pilgrim Station impact (Stone and Webster 1975 and 1977).

d - a dominant species in the Pilgrim area.

r - a local resident

c - commercial importance

s - recreational importance

I - impingement

E - entrainment

T/C - discharge current effects: thermal/current

* Note: Indicator species selection rationale: these three species were selected for assessment in 1992 because they have shown the most potential for impact off Pilgrim Station.

Plate 1. Biologist collecting length-frequency data from the catch of a commercial lobsterman in the proximity of Pilgrim Station. Lobsters constitute the area's most valuable fishery resource.

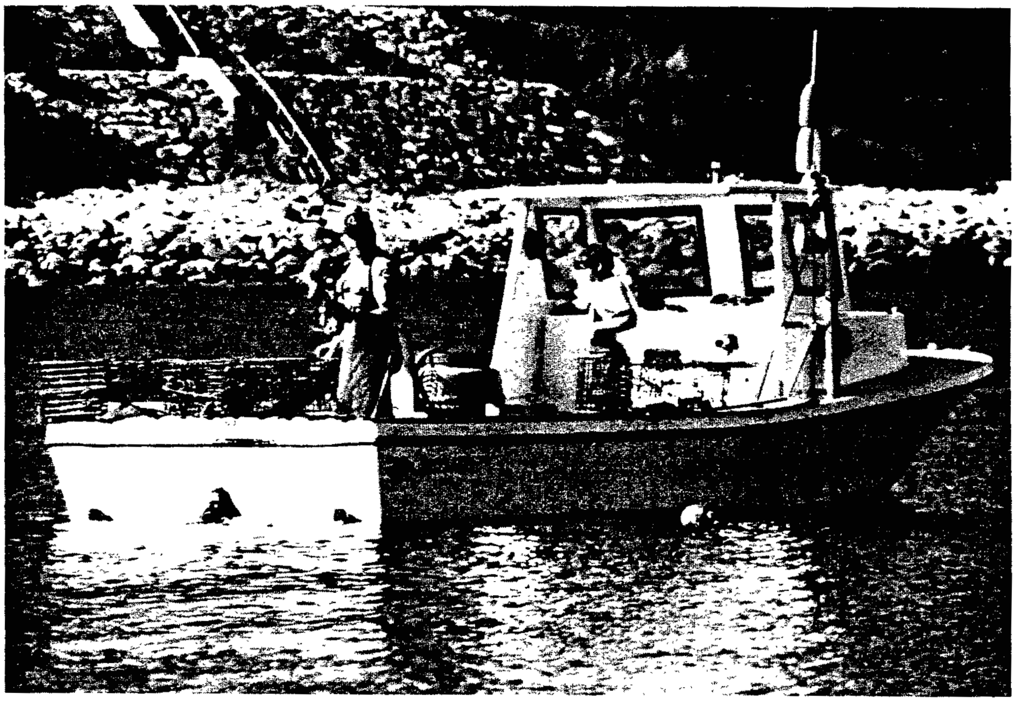

Plate 2. Operations aboard a fishing vessel used during the experimental lobster study. This investigation is designed to better assess the impact on lobsters of the thermal effluent at Pilgrim Station.

Plate 3. Retrieval of the experimental gill net after a standardized overnight set in the thermal plume area. Caught in the net is a smooth dogfish, a common summer migrant in the Pilgrim area.

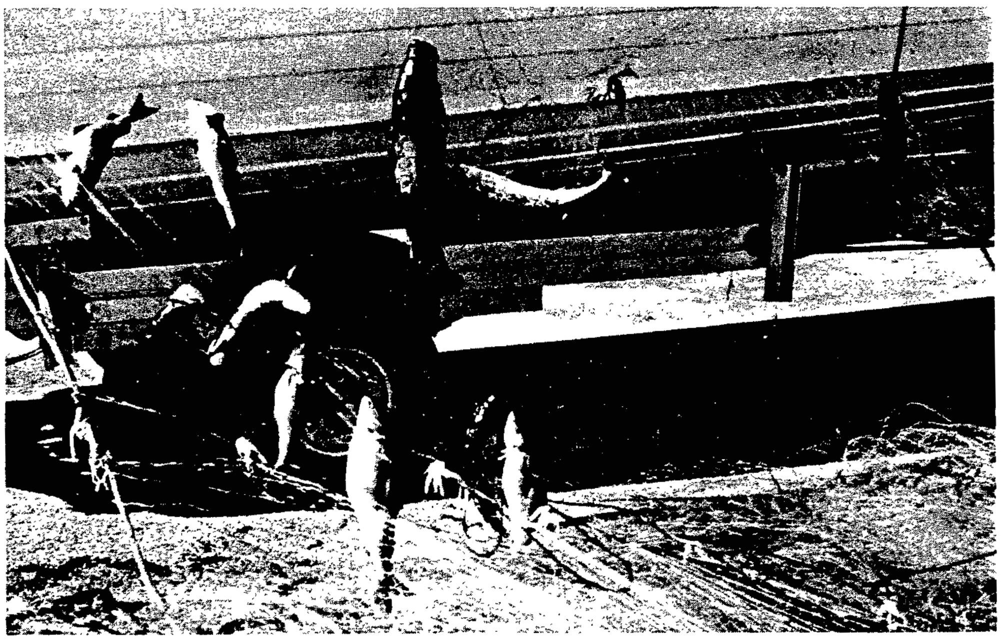

Plate 4. Fishes caught by gill net in the area of the thermal plume at Pilgrim Station. Gill-net catches include commercially important species, e.g., Atlantic cod, pollock, Atlantic mackerel, striped bass, and winter flounder.

Plate 5. Bottom trawl being set to sample groundfish in the inshore waters of western Cape Cod Bay. Catches are used to measure potential impacts of Pilgrim Station on the benthic fish community.

Plate 6. Typical trawl catch is processed which includes identifying enumerating, and measuring the different species for environmental assessment. Catches of winter flounder have been consistently largest at the Pilgrim Station intake trawl station.

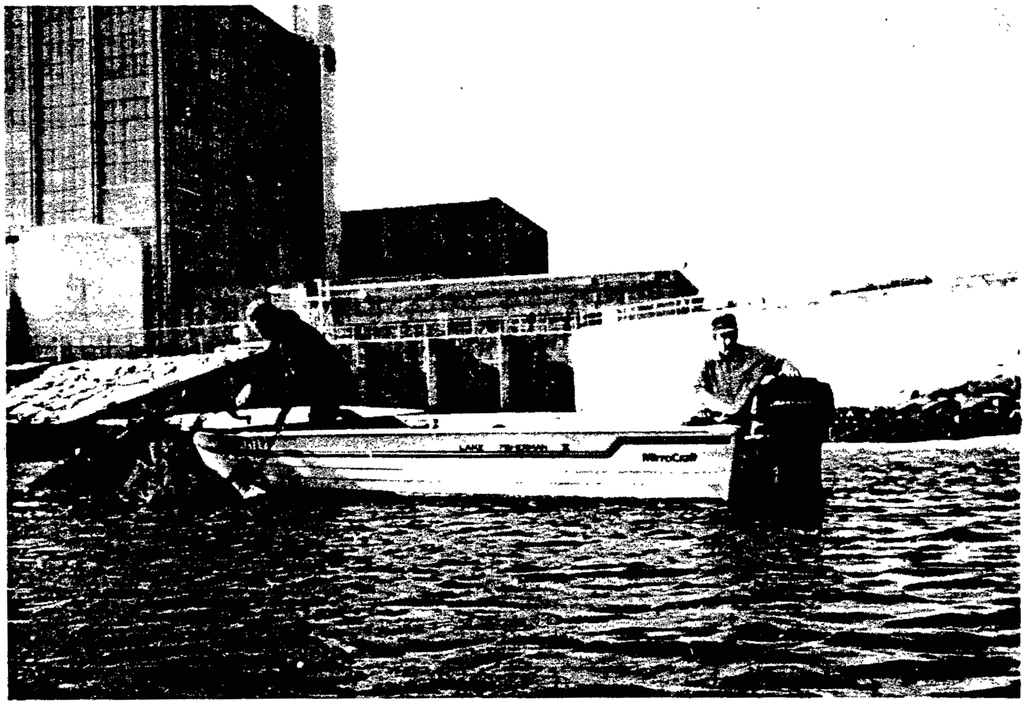

Plate 7. Haul seining in the intake embayment at Pilgrim Station: the net is being set from a powered-skiff to enclose a rectangular area. Seine catches can be integrated with impingement data for a more comprehensive evaluation of potential impact on shorezone fishes.

Plate 8. Haul seine catch processed on the beach near the Pilgrim Station intake (fish are enumerated and measured). Among the shorezone fishes are important forage fish such as the Atlantic silverside and sand lance, and the juvenile stages of several commercial species such as the winter flounder and Atlantic menhaden.

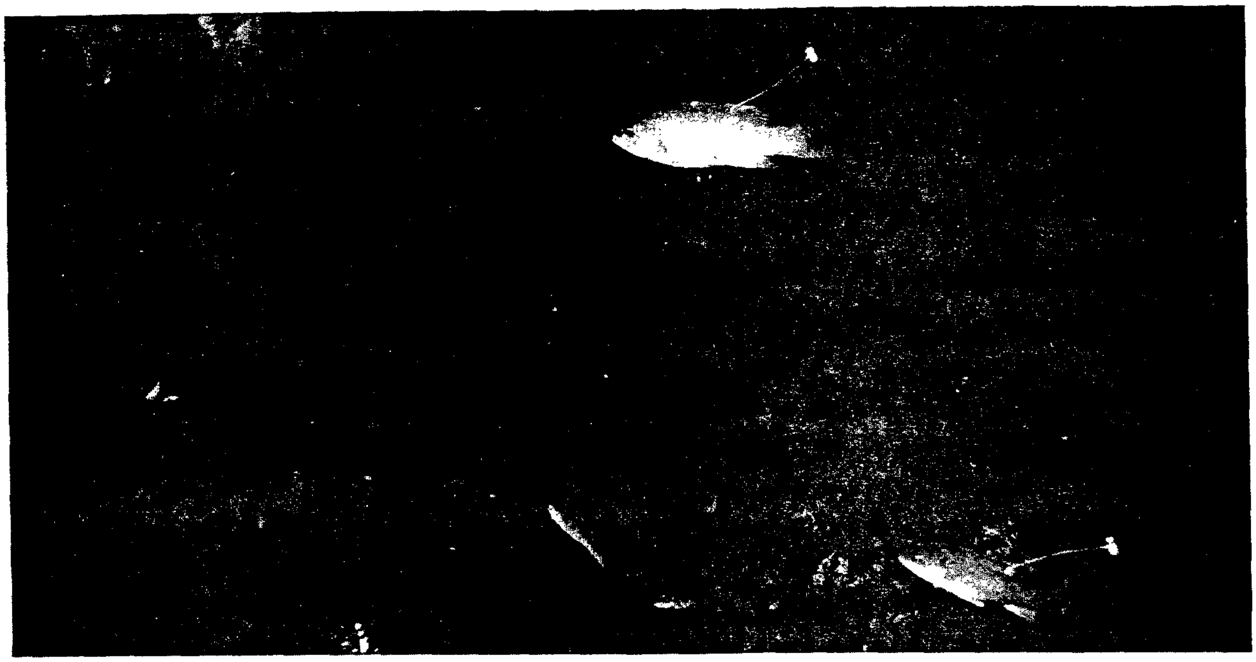

Plate 9. Tagged cunner seen swimming off the seaward side of the outer intake breakwater at Pilgrim Station. Diving observations have recorded the greatest number of fish sighted off Pilgrim Station to be cunner, which are structure oriented.

Plate 10. A winter flounder on the bottom near diving Station D_1 (~ 50 m, seaward of the discharge canal) in the "denuded" zone off Pilgrim Station. An important commercial and recreational fish, flounder inhabit the Pilgrim area throughout the year and have been used as an "indicator" species to assess stress imposed by the release of the heated effluent.

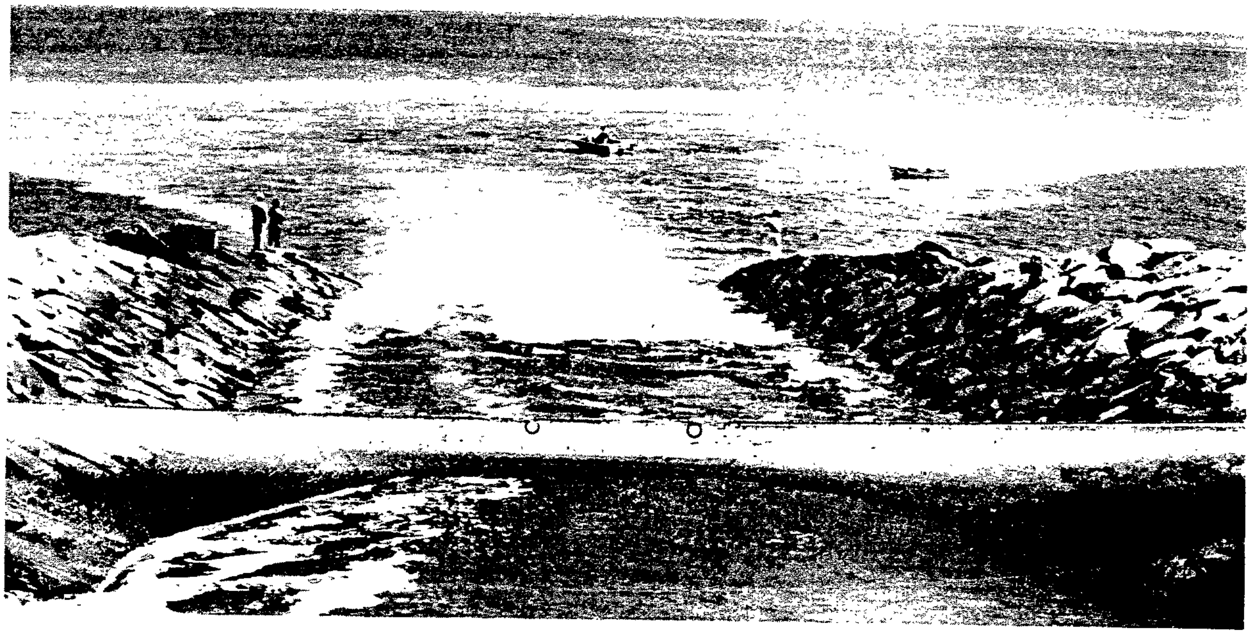

Plate 11. Pictured is the thermal effluent discharging into Cape Cod Bay, and anglers fishing off the discharge jetties and from boats in the plume which is visible in the background as the calm water. Striped bass and bluefish, which are attracted to and concentrate in the thermal current, are the dominant species sought by sport fishermen at this location.

Plate 12. Striped bass aggregate in the thermal discharge current at Pilgrim Station, often swimming just off the bottom into and out of the discharge canal. Bass are attracted to moving water as a feeding ground.

III. RESULTS AND DISCUSSION

A. PHYSICAL FACTORS

1. Power Output-Thermal Capacity

Pilgrim Station's capacity factor (MDC net percent) is an index of operational status that approximates thermal loading into the receiving waters. The plant is allowed by regulatory permit a maximum temperature rise of 18° C (32° F) above ambient. During the 20-year history of station operation, overall MDC has averaged 49.0%, with annual values ranging from 0.0% (outage years) to a high of 84.4% (Figure 1). The power level rose from 58.4% in 1991 to 80.6% in 1992. The latter value is the highest level of the last seven years. In 1992, thermal capacity ranged from 13.7% in November to 99.4% in February.

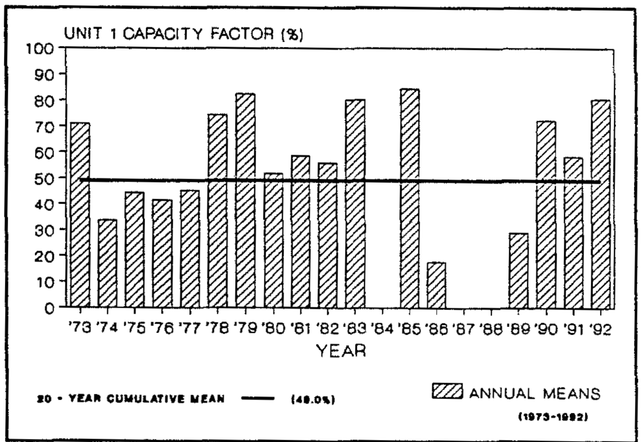

Figure 1. Annual means and 20-year cumulative mean Capacity Factor (MDC Net %) for Pilgrim Nuclear Power Station, 1973-1992.

2. Discharge Current

The two circulating seawater pumps at the Station induce a localized current as the once-through, open-cycle cooling water system draws in water from the Intake channel and discharges it back to Cape Cod Bay laden with waste heat. The effluent often exceeds velocities of 2.1 m/sec (7 ft/sec) at low tide at the egress of the discharge canal. This results in an erosional effect on the benthic environment in the path of the thermal plume.

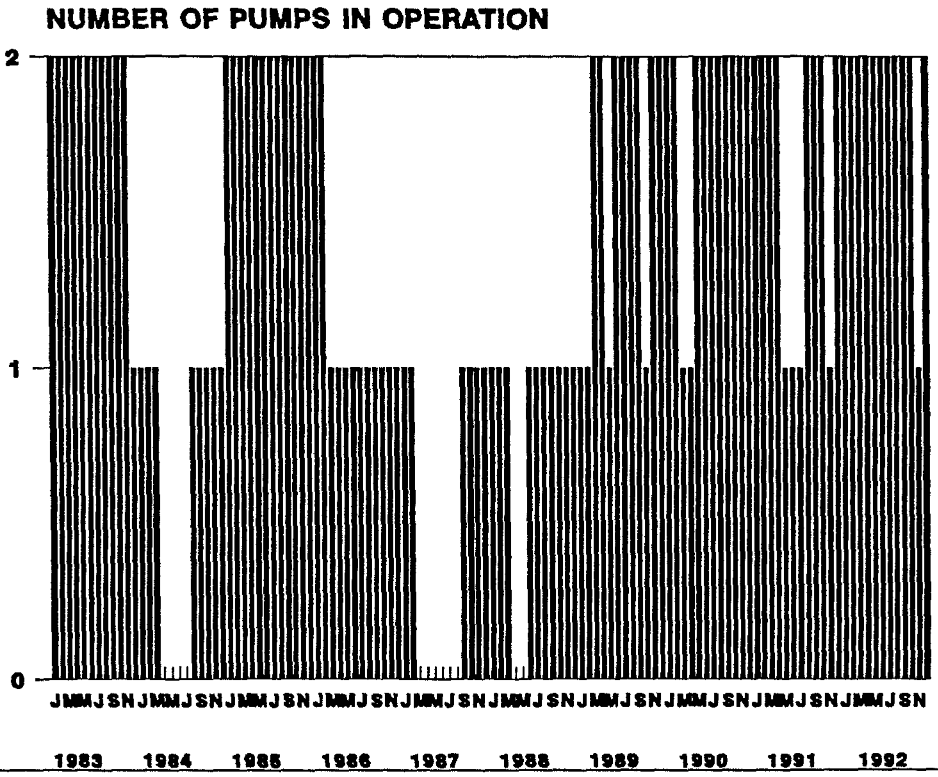

Figure 2. Operational history of the two circulating seawater pumps at Pilgrim Station by month for the years, 1983-1992.

There have been block periods of time when one or both circulating pumps were off during prolonged plant outages, e.g., in 1984, and 1986-1988 (Figure 2). In 1992, both pumps generally were run throughout the year except in November (short outage), when only one pump was on.

3. Water Temperature

Surface water temperatures (average of point measurements) were generally higher in the discharge area (Area 3) in 1992, a high operational year, except during the winter season when warmer temperatures were recorded in the deeper intake channel (Figure 3).

Over the last five years (Figure 4), seasonal means were highest in the outfall in 1990 and 1992 (high operational years).

The highest water temperatures occur at the surface during the summer. Temperatures were generally higher at the surface than on the bottom both spring and summer, but in the fall this was reversed as surface waters cool with declining air temperatures.

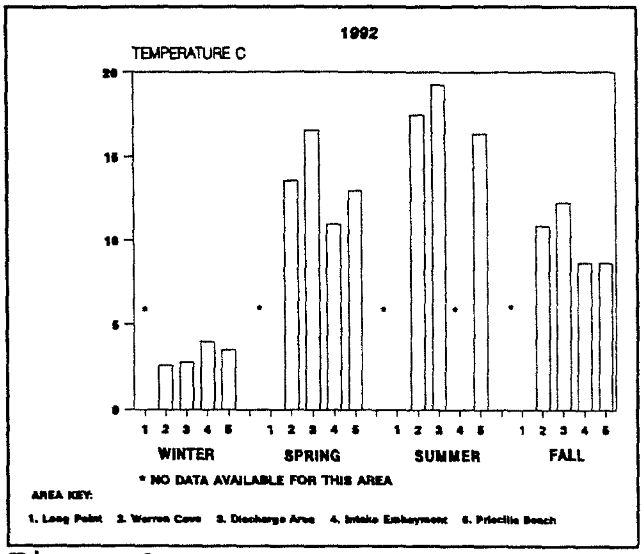

Figure 3. Surface water temperatures (° C) in the Pilgrim Station area by location, averaged by season for 1992.

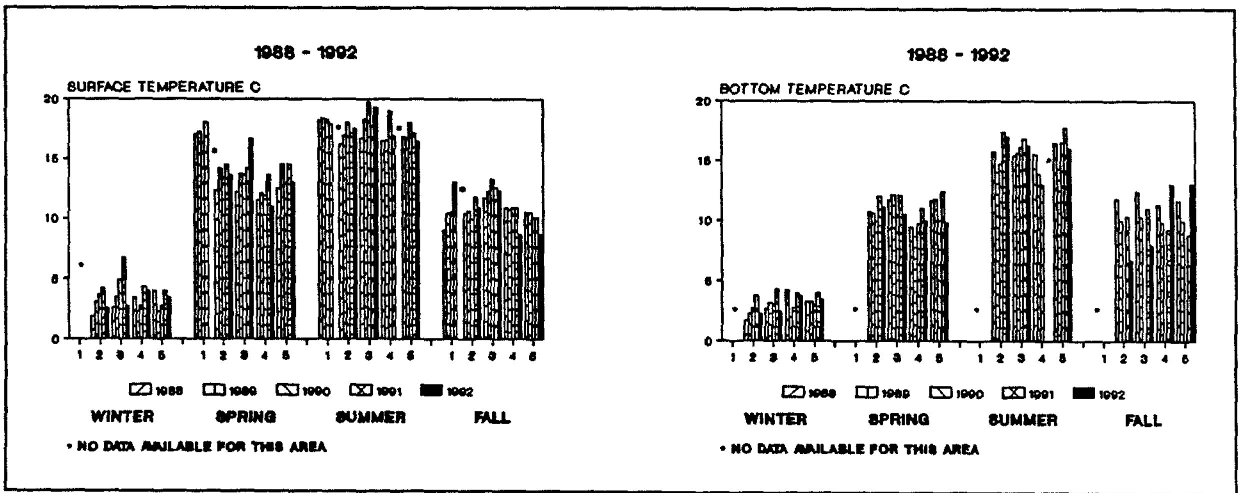

Figure 4. Surface and bottom water temperatures (° C) in the Pilgrim area by location, averaged by season for the years 1988-1992.

B. IMPACT OF PILGRIM STATION ON INDICATOR SPECIES

1. Cunner

Background

Cunner are resident groundfish in the inshore waters off Pilgrim Station. Being shelter dependent, they reside in rocky areas that abound off the Plymouth shoreline, including the man-made breakwaters and jetties at the power station. Olla et al. (1975) reported the home range of cunner to be restricted to the structure to which they were originally recruited. Cunner occur in discrete populations and are more likely to be measurably affected by point-source pollution than a species which exists as essentially one interbreeding population throughout an extensive geographical range, e.g., Atlantic menhaden.

Cunner have small home ranges (Green 1975) and, as such, may be exposed to increased sportfishing mortality and potential effects of inshore pollutants, making it a good indicator species to assess power plant impact. From recaptured fish in our cunner tagging work off Pilgrim Station, we have evidence of their site tenacity. Cunner are especially vulnerable to stress after dark, because low responsiveness to stimuli, characteristic of the sleep state of labrid fish, reduces their ability to avoid environmental perturbations that might occur at night.

Gill-net, diving, and creel sampling reveal that cunner has been a dominant fish species off Pilgrim Station. The power plant's intake breakwaters and discharge canal jetties provide added structure to the naturally occurring glacial till to provide habitat for a temperate-water reef community, of which the cunner is a member. The large boulders provide shelter imperative to cunner's sleep phase and cover to avoid discharge current velocities that might impair their maneuverability.

Typically distributed at depths of 3 to 10 m, some cunner occur in deeper water (Grosslein 1969). Year-round residents throughout much of their range (Green and Farwell 1971; Olla et al. 1975), cunner move seasonally to deeper water to escape cold temperatures. In the Gulf of Maine (Bigelow and Schroeder 1953) and off Newfoundland (Green and Farwell 1971), cunner activity was found to decrease at water temperatures below 8° C. Olla et al. (1975) found that in the fall at temperatures of 5-6° C, cunner become inactive and then torpid, remaining so until the water warms above 6° C in the spring.

Life Stages Impacted and Sampling Protocol

Potentially, cunner could be impacted by Pilgrim Station via mechanical and waste heat/current effects. Cunner probably spawn near the power plant, as we have captured ripe individuals seaward of the outer intake breakwater in May and June. Because of the cunner's local distribution and in that their eggs and larvae are pelagic, these early life stages are subject to entrainment in the plant's circulating seawater system.

Routine entrainment sampling at Pilgrim Station provides quantitative data on cunner eggs and larvae drawn into the plant's condenser tubes. Juveniles and adults (aged up to 8 years old) occur off the plant, including in the intake embayment, and are subject to impingement on the travelling-water screens. Impingement data routinely collected at the plant provide information on plant-induced effects and seasonal occurrence of cunner. The discharge current, laden with waste heat and periodically with chlorine, can influence all life stages of cunner in the receiving waters. Gill-netting, observational diving, and a sportfish creel survey together with tagging provide data on cunner in the discharge area and its environs. Cunner are expected to be most affected by station operation during summer and fall when they are active and most abundant off Pilgrim Station.

Conditional Mortality

Impingement

Adult and juvenile cunner have been entrapped on the intake screens at Pilgrim Station. This species is among the dominants impinged during years of Pilgrim operation (Lawton and Anderson et al. 1984). In 1992, cunner were impinged from February - August. An estimated 34 were taken for the period. Over the years, the majority of cunner have been impinged from June through September.

Impingement can be relatively high as it was in 1980, with about 1,700 cunner affected at Pilgrim Station. There is some survivorship of impinged cunner at the power plant, e.g., 24% in 1989 (Anderson 1990). Nevertheless, an impingement of this magnitude potentially could impact the local population in a given year when combined with sportfishing mortality and depressed stock size. There is mounting evidence that the present population has been declining in abundance.

Entrainment

Large numbers of cunner eggs and larvae are entrained at Pilgrim Station every year. The Labridae - *Pleuronectes* groups dominate collections of fish eggs at the station during the history of plant operation, comprising over 90% of the eggs entrained.

Johansen (1925) reported cunner spawn from May to August in New England and Canadian waters, while Williams (1967) documented that spawning occurred at temperatures between 10°- 26° C. In 1992, cunner eggs were entrained at Pilgrim Station from May-September but were most abundant in July samples (Mike Scherer, personal communication)[1]. Over the years of plant operation, cunner eggs have been entrained as early as March or April when ambient water temperature has been as low as 2.6° C (Scherer 1984). Scherer (1984) hypothesized that mature cunner may ripen and spawn earlier in the area warmed by the thermal discharge.

In 1992, cunner larvae were entrained at Pilgrim Station beginning in June, while the last larvae were collected in September. Unusually high densities of cunner larvae were entrained in June of 1989 and in July and August of 1990. Conversely, densities were relatively low in 1991 and 1992, with an atypical drop in larval density in July of both years.

Marine Research, Inc. (1991) concluded that large quantities of spawn (fish eggs and larvae, with a high percentage being cunner) have been entrained annually at Pilgrim Station and are

[1]Michael Scherer, President, Marine Research, Inc., Falmouth, MA.

assumed to be lost from the respective populations. As to conditional mortality, Pilgrim Station entrained 1.75 X 10^9 eggs and 2.56 X 10^6 larvae of cunner in 1992, which equates to 33,815 adult fish as estimated by an adult equivalency analysis (Mike Scherer, personal communication). With a mark-recapture population estimate of less than 5,000 adult cunner larger than 10 cm residing off the Pilgrim outer intake breakwater during the summer of 1992 (see Volume 1), the magnitude of entrainment loss initially seems substantial. However, at present, the limits of the local cunner population north and south of the Pilgrim Station breakwaters have not been defined. In addition, the amount of recruitment via egg and larval drift from these and other locales into the Pilgrim area is unknown but is likely of some consequence (Mike Scherer, personal communication). With a three-day incubation period at 15.6 ° C for its buoyant eggs and a three-week pelagic larval stage (Bigelow and Schroeder 1953), cunner could well recruit into the Pilgrim Station area from offsite spawning grounds via the predominant counter-clockwise current in Cape Cod Bay. Further knowledge of the areal extent of the local cunner population and recruitment to it is needed to assess plant impact.

Discharge and Sportfishing Effects

Population size

In 1992, cunner ranked third, as it has traditionally, in the hierarchy of gill-net catch off Pilgrim Station. The local population appeared to be fairly stable from 1973 to 1976 (Figure 5); over these years, the annual catch rate was 22 cunner per standard gill-net set. From 1977 to 1983, the yearly catch rates generally doubled (average of 41 fish per set). This suggests there was a marked change in availability, distribution or abundance of cunner in the Pilgrim area. The catch rate gradually declined from 1981 to 1984, dropping sharply in 1985 and remaining at a low level thereafter. Over the last seven years, the gill-net catch rate of cunner has declined by 70% from the mean of the previous eight years, averaging only about 11 fish per set. The 1990-1992 catch rates of recruitable cunner are the lowest on record (Figure 5).

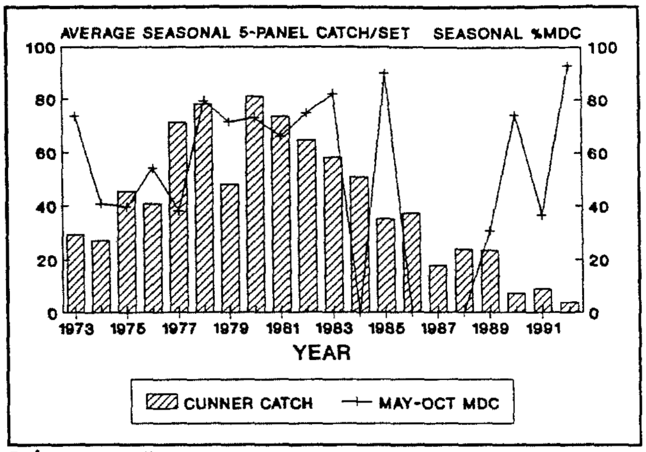

Figure 5. Average seasonal standard 5-panel gill-net catch for cunner and respective seasonal MDC Net % at Pilgrim Station, 1973-1992.

Discharge:thermal/current

Temperature tolerance data on cunner (Kinne 1969) suggest that the waste-heat effluent from Pilgrim Station should not cause overt mortality of this species outside the discharge canal. However, during the late summer and early fall when ambient water temperatures peak in Cape Cod Bay (Lawton et al. 1983), if the power plant is fully operational, there likely is an exclusion area to cunner within and just outside the confines of the discharge canal. Observations during our research dives in the discharge area (limited to flood tide) in August and September 1992 revealed there were substantially fewer cunner at the mouth of the discharge than out at 60 m in the path of the thermal plume. We measured bottom temperatures in excess of 30° C in these months at the discharge canal mouth. Kinne (1969) reported the upper thermal tolerance for adult cunner to be 29°-30° C at an acclimation temperature of 18°-22° C. Thus, late summer temperatures can be stressful to cunner in the discharge area and would be avoided if possible. Avoidance of the rapid discharge current could also be a factor.

During spring, temperatures in the thermal plume outside the effluent canal at Pilgrim Station are ideal for the hatching of cunner eggs. According to Williams (1967) cunner hatching occurs in less than 48 hours at 21.1°-22.2° C. The preferred temperature range of adult cunner is 13°-26° C (Stone and Webster 1975). In autumn, ideal conditions for cunner growth should exist immediately outside Pilgrim's discharge channel.

We graphed seasonal (May-October) plant output, i.e., thermal capacity, for the period when cunner are most active inshore, versus the May-October gill-net catch rates for cunner over the years (Figure 5). When catch rates were statistically regressed on seasonal power plant MDC for operational years, we found no significant relationship ($P = 0.35$).

Twelve years of underwater finfish observations off Pilgrim Station, which totaled 156 SCUBA dives, revealed that cunner has been the numerically dominant species in the vicinity of the outfall. For example, in 1990, 1991, and 1992, 53%, 64%, and 46%, respectively, of the fish sighted by project divers were cunner.

The cunner diving abundance index fell 70% from 93.8 cunner-per-dive in 1991 to a time-series low of 29.0 in 1992.

Diving observations suggest that cunner 5 cm and larger are attracted to Pilgrim's effluent at high tide. Woolner and Lyman (1984) write that bottom-feeding fish, for the most part, are more active when the tide is moving as opposed to slack. During plant operational periods at high tide, we have observed greater numbers of the larger-sized cunner in the faster current region of the 'denuded zone' than in either of the peripheral 'stunted' or 'control' zones. Even without a great amount of waste heat being released at the station, the generation of a water current produced by at least one of the two circulating seawater pumps at Pilgrim Station is of sufficient velocity to shift the small-scale spatial distribution of cunner by size class. However, during times when little or no discharge current was released from the power station, more cunner generally have been seen in the 'control' area.

Cunner are attracted to moving water to feed, as they will forage on surfaces exposed to current for epifaunal and infaunal prey and in the water column for planktonic organisms. Olla et al. (1975) observed that when cunner are feeding in the water column with a current present, they will face into the moving water while visually searching for food to be carried by them in a 'scan-and-pick feeding mode'.

It is known that small cunner, e.g., 2-3 cm fish (young-of-the-year), do not move far from their home shelter. Furthermore, the speed of the effluent current at Pilgrim Station, which can exceed 2.1 m/sec (7 ft/sec) at the egress of the discharge canal, becomes a limiting factor to these small fish in the discharge when the plant is operating. With small cunner in the Pilgrim area, if the plant is operational, these individuals most often reside in the 'control' area. Auster (1987) found at different sites throughout New England that larger cunner foraged further from reef substrate and on current exposed surfaces for longer time periods. As current velocity decreased, smaller size classes of cunner moved up into the water column out of the reef infrastructure and onto current-exposed surfaces to feed. As the speed of the current increased the process was reversed.

Sportfishing Effects

During some of our past creel surveys at the Pilgrim Station Shorefront, cunner led the shore-based sportfish catch. Cunner are caught readily by anglers bottom fishing off the outer intake breakwater at the Station. They ranked second in the sportfish catch at the Shorefront in 1991. Although none reportedly were caught in 1992, we feel this is somewhat due to incomplete reporting and also to many anglers targeting bluefish, striped bass, and winter flounder. We had fair success trapping cunner in baited pots off the outer intake breakwater this year.

Cunner have small home ranges which they occupy for an extended time (Green 1975) and are susceptible to increased sportfishing mortality. Most cunner caught at Pilgrim Shorefront by anglers have been allowed to die, and fishing mortality on the local population has been high in the past. In 1983 and 1985, for example, about 2,600 and 3,500 cunner, respectively, were caught by anglers at the Shorefront. Interestingly enough, the gill-net catch rate of cunner for 1985 dropped precipitously off Pilgrim Station. To address fishing mortality, we have encouraged fishermen, via posters placed at the Shorefront, to release their catch alive if not kept for consumption.

2. <u>Lobster</u>

Background

An inhabitant of the inshore waters of New England, the American lobster is one of the most common members of the nearshore benthic community. They are highly prized and subject to intense commercial and recreational fishing. In the Pilgrim Station area, lobster commonly are found sheltered in boulder "fields", under rocky ledges, and even in depressions on open sand. Lobster are most active at night when they range out from cover to forage for food. Moving inshore in spring as water temperatures rise, they remain in the nearshore area until cooling waters in late-fall trigger an offshore migration. It is during their stay inshore that lobster are subject to impact of Pilgrim Station.

Impact and Sampling Protocol

The potential for impact on lobster resulting from power generation at the Pilgrim site is greatest during the juvenile and adult life stages as few larvae have been entrained.

We rely on data generated by our commercial and experimental trap sampling programs to assess plant impact. It is noted, however, that measurement of plant effects can be confounded by other factors. Bay-wide environmental conditions such as short and long-term water temperature patterns can affect the timing of migrations, movements, and even delay or accelerate the onset of the molt. When combined with fishing pressure, plant effects may be masked and difficult to measure.

Conditional Mortality

Entrainment

Since 1974, only 11 lobster larvae have been recorded in entrainment sampling at Pilgrim Station (Marine Research, Volume 1, 1991). No larvae were collected in 1992. From these data, it is readily apparent that entrainment at Pilgrim Station poses no threat to larval lobster.

Impingement

A total of 69 sublegal lobster (mean size 39 mm CL) was sampled on Pilgrim's intake screens in 1992. This equates to an estimated impingement of 783 lobster in 1992. Such a mortality of adolescent phase lobster from impingement on the screens at Pilgrim Station is likely negligible to the population. The area immediately in front of the intake wall is not good habitat for lobster, and does not attract large numbers.

Discharge Effects - Heat and Current

Commercial Catch Data

We use commercial catch data collected in the vicinity of the power plant to assess impact of Pilgrim Station's thermal effluent on lobster. We divided the sampling area into quadrats (see Figure

3 in Volume 1). Quadrats H-11, H-12, I-11, and I-12 form the surveillance (discharge) area, and quadrats E-13, E-14, and F-13, the control. Data from these quadrats are pooled within their respective groupings for comparison (Figure 6).

Overall catch-per-pot of legal (≥82.6 mm CL) lobster in 1992 was 0.32 in the impact area and 0.18 in the control area, a decrease from 1991 when the catch rates were 0.35 for both areas. We compared our sampling data with Division of Marine Fisheries sampling statistics for western Cape Cod Bay using the Kruskal-Wallis test and found no significant difference ($P = 0.148$) in the data sets. As commercial landings for all of Cape Cod Bay have declined since 1990 (Estrella and Cadrin 1992), we believe our data reflect bay-wide effects. Due to cool spring water temperatures, the 1992 molt was apparently delayed, and peak landings, which normally occur in August and September, were pushed forward to October and November (B. Estrella, personal communication)[1].

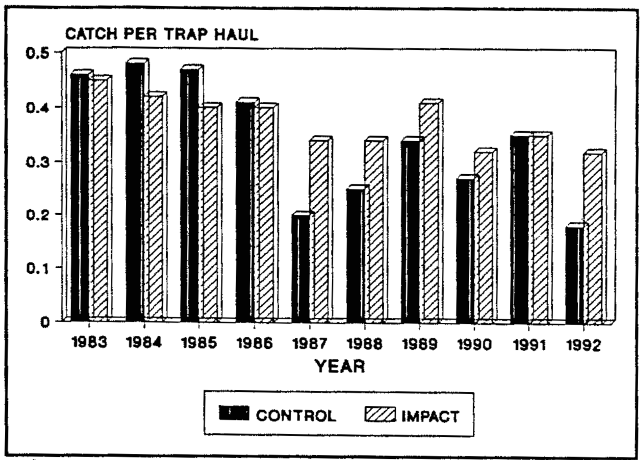

Figure 6. Annual commercial legal lobster-catch-per-trap-haul in control and impact areas in the vicinity of Pilgrim Station, 1983 to 1992.

Data from commercial catches in the control and impact areas were examined for differences for the period 1983 to 1992 using the Mann-Whitney U test. No significant differences were found (P =

[1]Bruce Estrella, Coastal Lobster Investigations, Division of Marine Fisheries, Sandwich, Massachusetts.

0.35). Using the non-parametric Kendall's coefficient of rank correlation, we found no relationship ($P > 0.05$) between thermal output (seasonal % MDC) and catch rate of legal and sub-legal lobster in the impact area. Differences in commercial catch rates over the years of our study most likely reflect factors other than plant operation.

Research Trap Catch Data

Our research trap study concluded its seventh year in 1992. As noted in Volume 1 of this report, management-directed gauge increases (the minimum carapace length (CL) of lobster that can be retained by fishermen increased from 80.96 mm (3.19 in) to 82.55 mm (3.25 in)) in 1988 and 1989 necessitated installation of larger escape vents in traps used by commercial and recreational fishermen. However, in order to maintain the integrity of our time-series data, we continued to sample traps outfitted with the old (smaller) vent. A comparison of catch rates from traps fished side-by-side with old and new vents was undertaken by the Division's Coastal Lobster Project in 1992 (Estrella and Cadrin, unpublished data). Subsequent analyses revealed no significant difference ($P = 0.07$) in the retention of legal-sized lobsters between the two vent sizes. However, traps equipped with the old vent were found to retain significantly more ($P < 0.01$) sublegal lobsters. From this, we believe increased catches of sublegal lobster (relative to the capture of legals) in our traps in recent years (see Figure 7 in Volume 1) can be attributed to management changes rather than impact from Pilgrim Station.

Legal CTHSOD data for 1992 were pooled by station within areas and then compared by area on a monthly basis using the Kruskal-Wallis test. No significant differences ($P > 0.05$) were found. In 1991, the Discharge was found to have a significantly lower catch rate of legals than Priscilla Beach in July and Rocky Point in September. Sublegal catch rates also were analyzed with the Kruskal-Wallis test using the same format as the legal catch rate data. There were no significant differences ($P > 0.05$) amongst the sites. These findings differ from 1991, when Discharge sublegal catch rates were lower than Rocky Point in July and August. As with the commercial sampling data, catch rates in our experimental pots are likely influenced by other factors (water temperature, fishing and natural mortality, etc.).

To identify any relationship between Pilgrim Station's thermal output and lobster catch at our Discharge stations, we plotted monthly catch rates against seasonal plant MDC and tested these data using linear regression and Kendall's concordance of correlation. No relationship was discerned.

The ratio (Thomas and Van Voris 1986) of catch rate obtained at the discharge site (pooled for stations) to the average of the two reference sites (pooled station data) calculated for each year of the study is found in Figure 7. A grand mean ratio for legal and sublegal catch rates from the extended outage (unstressed) period at the plant (1986-1988) has been computed and serves to establish the relationship between areas. Acknowledging the intrinsic 'impossibility' of finding identical reference locations, this procedure measures impact by monitoring trend alterations in the impact/reference ratios.

A comparison of ratios for sublegal catch rates does not yield any pattern. Examining legal ratios shows higher catch rates in the Discharge area during the high output years of 1990 and 1992. Additional data from high operational years are needed.

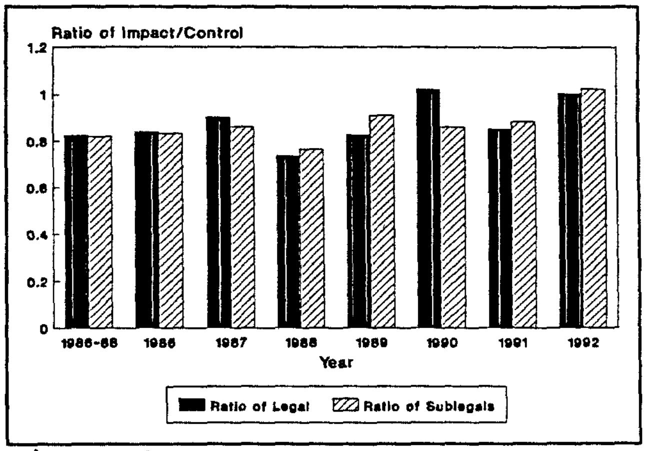

Figure 7. Impact/reference ratios for legal and sublegal catch rates from research lobster traps fished in the vicinity of Pilgrim Station, 1986-1992.

3. <u>Winter Flounder</u>

Background and Life History

Winter flounder occur in the Northwest Atlantic from Labrador to Georgia. In New England, most are caught in shoal water of bays and estuaries. Spawning occurs when water temperatures are at their lowest during late winter and early spring in estuaries, over shoals outside of estuaries, and on offshore banks. The eggs are demersal and adhesive, and the larvae are relatively non-buoyant. Nursery grounds, which are in the general vicinity of spawning areas, are found in saltwater coves, coastal salt ponds, protected embayments, and estuaries - including riverine systems. The juveniles remain in or near their shallow natal waters for about two years (Buckley 1982). These conditions give winter flounder a degree of geographic isolation, which helps to define population units.

Lux et al. (1970), Howe and Coates (1975), and Pierce and Howe(1977) demonstrated that winter flounder north and south of Cape Cod exist as separate groups based on fin ray counts and tagging. Tag returns from release sites north of Cape Cod revealed that movement of adult flounder was limited from inshore grounds (Howe and Coates 1975) and that movements apparently reflect the extent of seasonal dispersal.

Based on meristic data, estuarine population units do not constitute separate genetic or biological units. Distinct groups consist of an assemblage of adjacent estuarine spawning units. Pierce and Howe (1977) concluded that the group north of Cape Cod can be managed as a separate stock. Within this north Cape Cod/inshore Gulf of Maine group, some estuarine spawning units appear more geographically isolated than others (Howe and Coates 1975), and in these cases, a local fishery might justify that an estuarine spawning population be treated as a unit stock.

Winter flounder in Cape Cod Bay basically exist in relatively localized populations (Stone and Webster 1977). Plymouth-Kingston-Duxbury Bay (PKDB) estuary is the area proximal to Pilgrim Station where intensive winter flounder spawning occurs. There are seasonal inshore and offshore movements within this area. Adults disperse from the winter estuarine spawning grounds after the spawn, moving into deeper, inshore water within Cape Cod Bay during spring and summer (Howe and Coates 1975). No commercial dragging is allowed inside state waters May-October; however, following the

November 1 opening, this local winter flounder population is exploited by an intensive trawl fishery.

The National Marine Fisheries Service reported a region-wide decline overall in winter flounder abundance that has extended from the 1980's into the '90's (NEFC 1991). The Massachusetts Division of Marine Fisheries' trawl surveys - both off Pilgrim Station (Lawton et al. 1992) and throughout state territorial waters (Witherell et al. 1990) - showed substantial declines in abundance of flounder north of Cape Cod subsequent to 1983 (Howell et al. 1992). Overfishing is a major contributing factor. Commercial landings from state waters within the Gulf of Maine declined rather steadily during the 1980's, with a high of 5.0×10^5 kg (1.1×10^6 lbs) in 1981 and a low of 7.9×10^4 kg (1.8×10^5 lbs) in 1989 (Howell et al. 1992).

Spawning success and stock cohesion are enhanced in areas where physiography leads to larval retention. The size of the spawning ground is important to the potentiality of population size. Large winter flounder populations are correlated to large spawning habitats that promote larval retention, e.g., large bays and offshore banks, whereas smaller populations are associated with coastal ponds and estuaries (Howell et al. 1992). Conditional mortality caused by a power plant via entrainment and impingement can have more of an impact on small populations.

Habitat quality is especially important because the location of flounder spawning grounds coupled with their limited movement patterns make this species sensitive to alteration and degradation of inshore aquatic habitats. Proximity of these areas to many anthropogenic activities predispose flounder to effects of dredging and filling of the marine environment, toxic pollutants, and power plant effects including thermal loading. These can lead to a loss of reproductive and growth potential.

Conditional Mortality

The circulating seawater system at Pilgrim Station results in impingement and entrainment of winter flounder along with other taxa and must be figured into total mortality of the species. Fish losses through impingement can be consequential where power plant intakes are in nursery areas. For example a power station in upper New Haven Harbor, Connecticut, has impinged 27,000 juvenile winter flounder annually (Normandeau 1979). Both juvenile and adult flounder inhabit Pilgrim's Intake embayment seasonally. Of the 141 young-of-the-year (2-10 cm) directly counted by our biologist-divers during our trawl diving transect program, 137 were found in the Intake, which serves as a mini-nursery ground. Young-of-the-year flounder inhabit relatively shallow coves because of their attraction to light, and their movements on nursery grounds are limited (Saucerman and Deegan 1991).

Impingement, however, has been relatively light at Pilgrim Station relative to many other power stations (Lawton, Anderson et al. 1984). In 1992, the estimated impingement of winter flounder at the Station was 817, of which the majority were young-of-the-year and yearlings.

Winter flounder larvae, but often not their eggs, are susceptible to entrainment. The flounder's demersal adhesive eggs facilitate their retention within spawning areas. However, once hatched, the larvae generally are more abundant near the bottom of the water column and therefore are subject to entrainment. Entrainment at Pilgrim Station over the last six years (1987-92) has ranged from 3.5 million to 17.9 million winter flounder larvae annually. Flounder entrainment in 1992 was 8.4 million larvae. The effect of entrainment mortality in '92, using the adult equivalent approach, which assumes a population in equilibrium and no compensatory mechanisms in operation, equates to the equivalent loss of 20,700 adult flounder (age-three fish). In this calculation, larval age-group survivorship values were taken from work done off the Millstone Nuclear Power Station (NUSCo 1987).

The stock origin of entrained larvae at Pilgrim Station is somewhat uncertain. The plant indeed entrains larval flounder from Plymouth-Kingston-Duxbury Bay but probably also entrains larvae produced outside this estuary in Plymouth Bight (Marine Research Inc. 1988). The evidence of larval flounder production in the Bight complicates our understanding of power plant impact, including the calculation of adult stock size.

Another concern is possible effects of waste heat on the activity and response of winter flounder in the outfall off Pilgrim Station. Direct mortalities of juveniles and adults have not been recorded here. Olla et al. (1969) observed flounder inactivity and burrowing in the substrate when water temperatures were above 22.2° C, which is below the incipient upper thermal tolerance limit estimated by McCracken (1963) at 26.5° C and by Gift and Westman (1971) at 28° C. To avoid stressful high water temperatures, flounder either will vacate an area, or bury into sand substrate which has a lower temperature than the overlying water (Olla et al. 1969). On several occasions in late summer of 1992, we measured bottom water temperatures in excess of 30° C at the egress of the Pilgrim discharge canal. Stone and Webster (1977) predicted that adult winter flounder are excluded by temperature from about 4047 m^2 (1 ac) in the immediate vicinity of the discharge during the summer and fall. This is not a particularly large impact area.

IV. CONCLUSIONS

Cunner

1. Although larval cunner densities at Pilgrim Station were relatively low in 1991 and 1992, numbers of cunner eggs and larvae were entrained from May through September in 1992, with the total entrained being equivalent to about 34,000 adult fish.
2. Over the past eight years (1985-1992), the gill-net catch rate of cunner has declined by about 75% from the previous eight years. The 1990-1992 catch rates are the lowest of the twenty-one year gill-net time series.
3. The 1992 cunner abundance index from the underwater finfish observations declined 70% from 1991 to a time series low.
4. Based on the declines of the various cunner abundance indices at Pilgrim Station, it appears that the cumulative effects of entrainment, impingement, and sportfishing may have contributed to a reduction in the local cunner population.
5. Stressful warm temperatures may cause cunner to avoid the discharge canal and near-thermal plume during late summer.
6. The discharge current at the station is of sufficient velocity to shift the small scale distribution of cunner by size class, with only larger cunner present in the discharge current on a flood tide.

American Lobster

1. As only 11 lobster larvae have been entrained at Pilgrim Station since 1974, and only relatively low numbers of

juveniles have been impinged, there is no apparent impact of the intake at Pilgrim Station on these life-stages of lobster.

2. Analysis of commercial lobster pot-catch data indicate there is no relationship in the annual catch ratios between the surveillance and reference areas and the operational status of the Power Plant. However, we have no control over positioning of the commercial gear spatially in the designated surveillance quadrats; lobster pots can be deployed far enough away from the discharge canal that the thermal current probably is not a major factor affecting lobster distribution.
3. We found no significant differences in catch-rates (legals and sublegals) between stations during analysis of research lobster pot-catch data for 1992. There was no relationship between catch-rates and seasonal plant MDC.

<u>Winter Flounder</u>

1. The location of the local winter flounder spawning grounds, the species' limited movement patterns, and the rather discrete population unit in the Pilgrim Station area make this flatfish susceptible to power plant effects and resultant conditional mortality.
2. Bottom trawl surveys and commercial landings point to declining winter flounder abundance north of Cape Cod throughout the 1980's and into the '90's.
3. The Intake embayment at Pilgrim Station is a mini-nursery area for winter flounder, subjecting especially young-of-the-year and yearlings to possible impingement on the plant's rotating

screens.

4. In 1992, an estimated 817 winter flounder, mostly YOY and yearlings, were impinged at Pilgrim Station.

5. Entrainment of flounder larvae poses more of a concern. In 1992, 8.4 million winter flounder larvae were entrained at Pilgrim Station, which equates to 20,700 age 3 adults.

6. In late summer, water temperatures in the immediate vicinity of the discharge canal exceed the upper thermal tolerance limit for winter flounder and would exclude them from a small area at the mouth of the discharge canal. This area of stress is under 4047 m^2 (1 ac).

VI. ACKNOWLEDGEMENTS

The authors thank the following staff members - Neil Churchill and Paul Caruso for assisting in field sampling operations. We acknowledge Chris Kyranos, a commercial lobsterman, for his valued assistance in our research lobster sampling program. Raymond Dand and Robert Ellenberger of Boston Edison Company (BECo) collected sportfish data at Pilgrim Shorefront. Jay Burnett from the National Marine Fisheries Service (NMFS) in Woods Hole, MA aged cunner from the Pilgrim area. A special thanks to Kim Trotto of our staff for word-processing several sections of this report. We appreciate the guidance of Robert D. Anderson of BECo, W. Leigh Bridges of our Division, and members of the Pilgrim Administrative-Technical Committee, especially Jack Parr of EPA and Carolyn Griswold of NMFS. Their input on various studies and editorial comments on project reports and papers have been most helpful.

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FINAL
SEMI-ANNUAL REPORT
Number 41

on

BENTHIC ALGAL MONITORING AT THE PILGRIM NUCLEAR POWER STATION (QUALITATIVE TRANSECT SURVEYS)

January-December 1992

to

BOSTON EDISON COMPANY
Licensing Division
25 Braintree Hill Office Park
Braintree, Massachusetts 02184

From

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
89 Water Street
Woods Hole, MA 02543
(508) 540-7882

5 April 1993

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to one or none (Figure 7). In addition, the discharge water remained at ambient temperature. As a consequence, the benthic community normally affected by these effluent parameters recovered, so that by 1988 there was essentially no difference between the control stations and the areas near the discharge canal.

Studies conducted after the power plant returned to full operation, with the resumption of electrical generation and the operation of either one or both circulating pumps, originally were designed to assess the impact of plant operation on a benthic environment that had returned to near ambient conditions. Quantitative faunal and algal monitoring studies and qualitative transect surveys were conducted through 1991. For the 1992 study season the monitoring program was restricted to seasonal qualitative surveys of the discharge area; community studies of the benthic algae and fauna were discontinued.

The percent of time that PNPS operated in 1992 was very high. Figure 7 depicts the monthly maximum dependable capacity (MDC) factor and circulating water pump operation of PNPS since 1983. The MDC is a measure of reactor output that approximates thermal loading to the marine environment. A maximum MDC value of 100% represents the highest allowable change in ambient temperature for water discharge to Cape Cod Bay (18°C ΔT). In 1992, the monthly maximum dependable capacity factor was greater than 94% for 7 months and above 50% for four of the remaining months. These high monthly capacity factors resulted in the annual capacity factor of 80.6% for 1992, an amount exceeded previously only in 1979 and 1985. In addition, both pumps were in operation for the 11-month period from December 1991 through October 1992 and again in December 1992. In 1992, the plant experienced only a mini-outage from the end of March until mid-April and a mid-cycle outage in November.

3.2 QUALITATIVE TRANSECT SURVEYS: 1983-1992

Results of the qualitative transect surveys from 1983 through 1992 are summarized in Figure 8. The total acute impacted area (denuded, sparse, and including the dense mussel zone seen in June, 1992) is plotted as well as the area of the denuded zone only and the monthly PNPS capacity factor (MDC). The difference between the denuded and total acute impact zones represents the sparse zone (and included the dense mussel zone in June 1992). A lag-time in recovery response by the acute impact zone to the 1984 PNPS power outage was reported in Semi-Annual Report No. 27 (BECO, 1986). Evidence of this slow recovery included a decrease in the area of the total acute impact zone that began in mid-1984 (5 months after the cessation of power plant operations) and continued through mid-1985. Between

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EXECUTIVE SUMMARY

This report presents results of field studies conducted for 1992 in the area affected by the thermal effluent flowing from the Pilgrim Nuclear Power Station (PNPS) and summarizes the potential impacts caused by the PNPS on algal distributions in the vicinity of the discharge canal. Field studies for 1992 were confined to qualitative transect surveys used to map algal cover in the area of water outflow and were performed in April, June, and September, 1992, and February, 1993. The last-mentioned survey, originally scheduled for December, was delayed due to weather and other complications. Because this survey was performed during the depths of the winter season the results should be comparable to those that would have been obtained in December. Field survey techniques were identical to those used in prior years. These investigations represent the most recent phase of long-term efforts to monitor effects of the thermal effluent on the benthic communities adjacent to the PNPS.

PNPS is a base-load, nuclear-powered electrical generating unit designed to produce 670 megawatts of electrical energy under full operational conditions. The station is cooled by water that is withdrawn from Cape Cod Bay and then returned to the Bay via a discharge canal designed to dissipate heat from the water through rapid mixing and dilution. Two circulating pumps produce a maximum water flow of approximately 20 $m^3 s^{-1}$. The cooling system at PNPS may affect the benthic community in three ways: 1) warming the ambient waters, 2) chemical discharges (mainly Cl_2), and, 3) increased current velocities that result in scouring of the seabed. Increasing temperature and chemical discharges may stress the algal community so that species composition and community structure change; the extent of such change depends upon season of the year and the influence of local oceanographic conditions. Increased current velocity directly affects the benthos by actually removing benthic organisms and preventing settlement and recolonization; intense bottom scouring may cause the rock surfaces to become bare and devoid of macroscopic marine life.

The qualitative transect studies performed to evaluate the *Chondrus crispus* community in the thermal plume area indicated that in April and June 1992 the condition of the denuded and total affected areas was typical of that seen in years prior to 1992 when the power plant was in full or nearly full operation. The denuded area (996 m^2), in April, was well within the size range seen in previous spring surveys taken when the plant was in operation (765 m^2 in April 1986 to 1321 m^2 in March 1991). By June, the denuded zone had increased 43% to 1429 m^2, an area exceeded only in one previous June (1990) survey. The sparse zone had disappeared by June and was replaced by a region densely packed with juvenile blue mussels (*Mytilus edulis*) measuring 0.5 cm in length. The carpet of tiny shells was so thick that it completely obscured *Chondrus* in the affected area making it impossible for the divers to map a stunted or sparse *Chondrus* zone. Dense mats of mussels were also observed in June 1990, although at that time the individuals were larger (1 to 2 cm in length) than those seen in 1992. It is likely that the June 1992 survey occurred nearer to the time the mussel larvae settled in the area than the survey performed in 1990. Although the total affected area was smaller in September than in June, the denuded zone (1569 m^2) was even larger than it had been in June and was exceeded in area only in one prior fall (1990) survey. Conditions in 1990 and 1992 that led to a large settlement of mussel larvae and consequent damage to the *Chondrus* plants may have resulted in the large total affected area seen in those years. In February, the areas of both the denuded (1315 m^2) and total affected zones (1491 m^2) had decreased from that seen in September and were each just slightly greater than seen in the winter surveys of 1990 and 1991.

1.0 INTRODUCTION

This report represents a continuation of long-term (19 years) benthic studies at Pilgrim Nuclear Power Station (PNPS) that are intended to monitor the effects of the thermal effluent. The 1992 program was limited to qualitative SCUBA surveys of algal cover in the thermal plume of the effluent within and beyond the discharge canal (Figure 1) that were planned for March, June, September, and December. Quantitative benthic algal and faunal samples were not collected in 1992. This Semi-Annual Report includes qualitative observations recorded in April, June, and September 1992, and February 1993 as well as a summary of the potential impact on algal distributions caused by PNPS. Work was performed under Boston Edison Co. (BECo) Purchase Order 69004, in accordance with requirements of the PNPS NPDES Permit No. MA 0003557.

2.0 FIELD STUDIES

2.1 METHODS

The qualitative algal survey is performed by SCUBA divers in the same location and with the same techniques that have been used since the beginning of the current monitoring program, approximately 11 years ago. SCUBA-equipped biologists operate from a small boat, and make observations along the axis of the discharge canal. A line is extended across the mouth of the discharge canal (Figure 2). A weighted central transect line (CTL), marked at 10-m intervals, is then attached to the center of this line and deployed along the central axis of the canal to a distance of 100 m offshore. Using a compass, divers extend a 30-m measuring line, marked at 1-m intervals, perpendicular to the

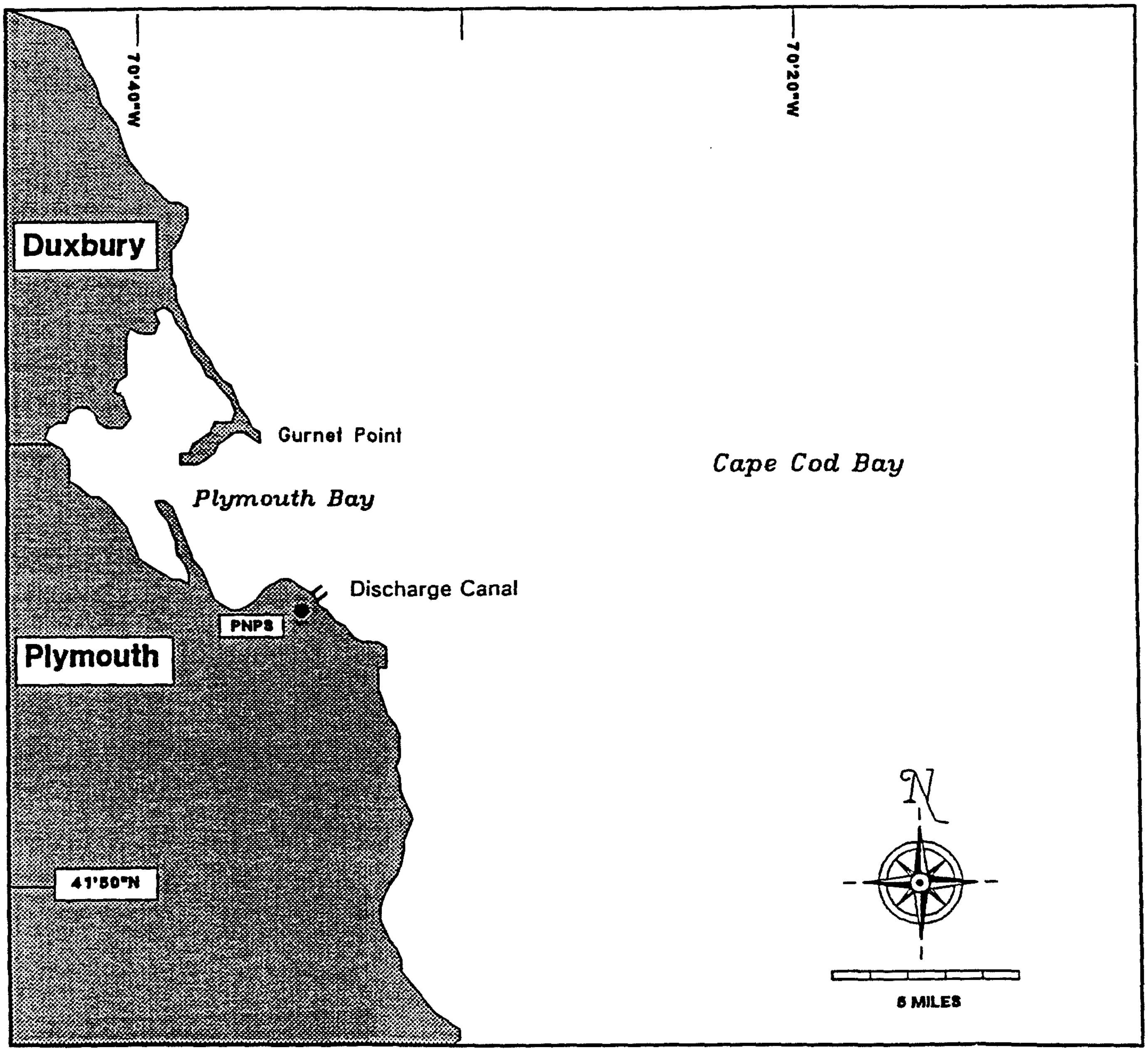


Figure 1. Location of Pilgrim Nuclear Power Station Discharge Canal.

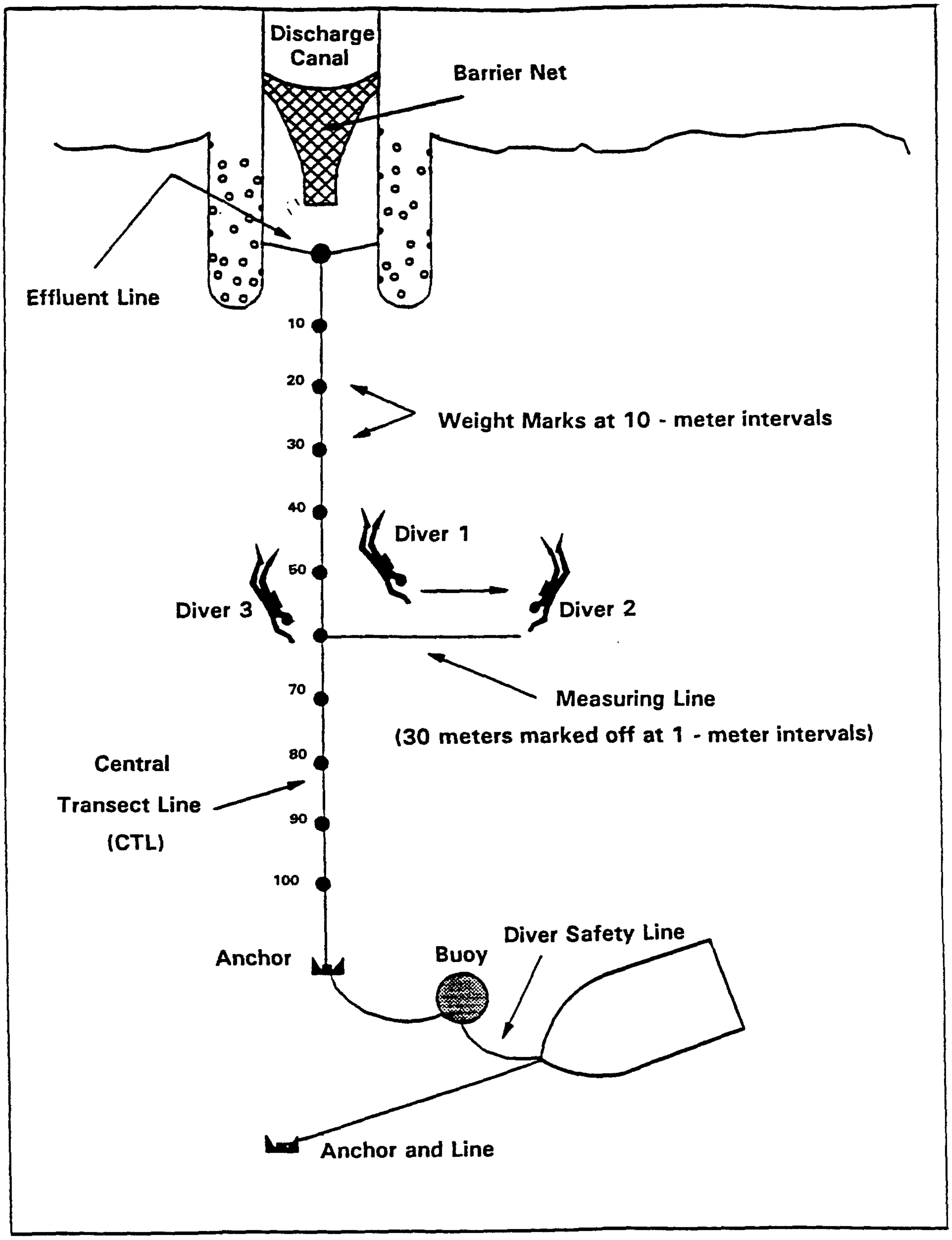


Figure 2. Design of Qualitative Transect Survey.

CTL. A diver swims along this third line, recording changes in algal cover from the CTL through the denuded and stunted *Chondrus* areas, until the algal cover looks normal.

According to procedures established by Taxon (1982) and followed in subsequent years, the distinction between "denuded" and "stunted" zones is based on the growth morphology of *Chondrus crispus*. Four designations are currently used to describe *Chondrus* growth zones. 1) The **denuded zone** is defined as that area where *Chondrus* occurs only as stunted plants restricted to the sides and crevices of rocks. In this area, *Chondrus* is found on the upper surfaces of rocks only where the microtopography of the rock surfaces creates small protected areas. 2) In the **stunted zone**, *Chondrus* is found on the upper surfaces of the rocks but is noticeably inferior in height, density, and frond development compared to unaffected areas. 3) In 1991 the divers included a distinction between a stunted zone and a "sparse" zone. The **sparse zone** is an area with normal-looking *Chondrus* plants that are very thinly distributed. 4) The **normal zone** begins at the point where *Chondrus* height and density are fully developed. The dive team must keep in mind while taking measurements that the shallow depths northwest of the discharge canal preclude normal *Chondrus* growth. In addition to observing algal cover, the divers record any unusual occurrences or events in the area and note the location of any distinctive algal or faunal associations.

2.2 RESULTS

Qualitative transect surveys of acute nearfield impact zones began in January 1980 and have been conducted quarterly since 1982. Four surveys were performed (April 9, June 16, and September 29, 1992 and February 10, 1993) during the current reporting period, bringing the total number of surveys conducted since 1980 to 48. Results of surveys conducted from January 1980 to June 1983 were reviewed in Semi-Annual Report 22 to Boston Edison Company (BECO, 1983). A summary of the surveys conducted between 1983 and 1991, including a review of the four surveys performed in 1991, was presented in Semi-Annual Report No. 39 (BECO, 1992). The present report summarizes the April and June 1992 surveys and presents new data from the September 1992 and February 1993 surveys.

Figures 3, 4, 5, 6, and 7 show the results of transect surveys performed by SCUBA divers. The denuded zone is essentially devoid of *Chondrus crispus* and the sparse zones are those in which normal looking *Chondrus* is sparsely distributed. The dense mussel zone, seen in June 1992 (Fig. 4), covered the entire denuded zone but is illustrated only for that affected area beyond the denuded zone where delineation of a stunted or sparse zone was impossible. A large boulder that is nearly exposed at mean low water, and that is used as a landmark by both the Science Applications International Corporation

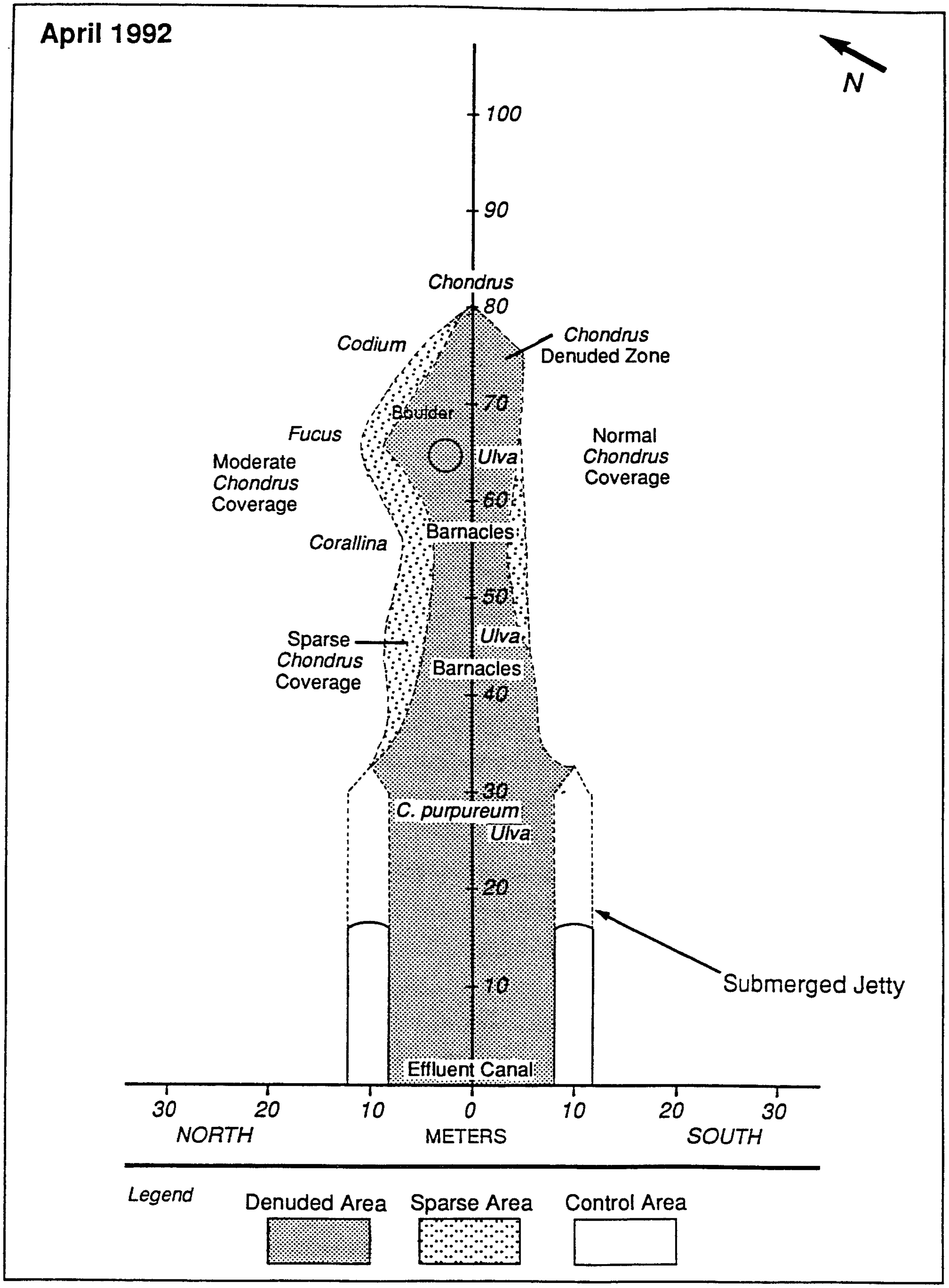


Figure 3. **Denuded and Sparse *Chondrus* Zones Observed in April 1992.**

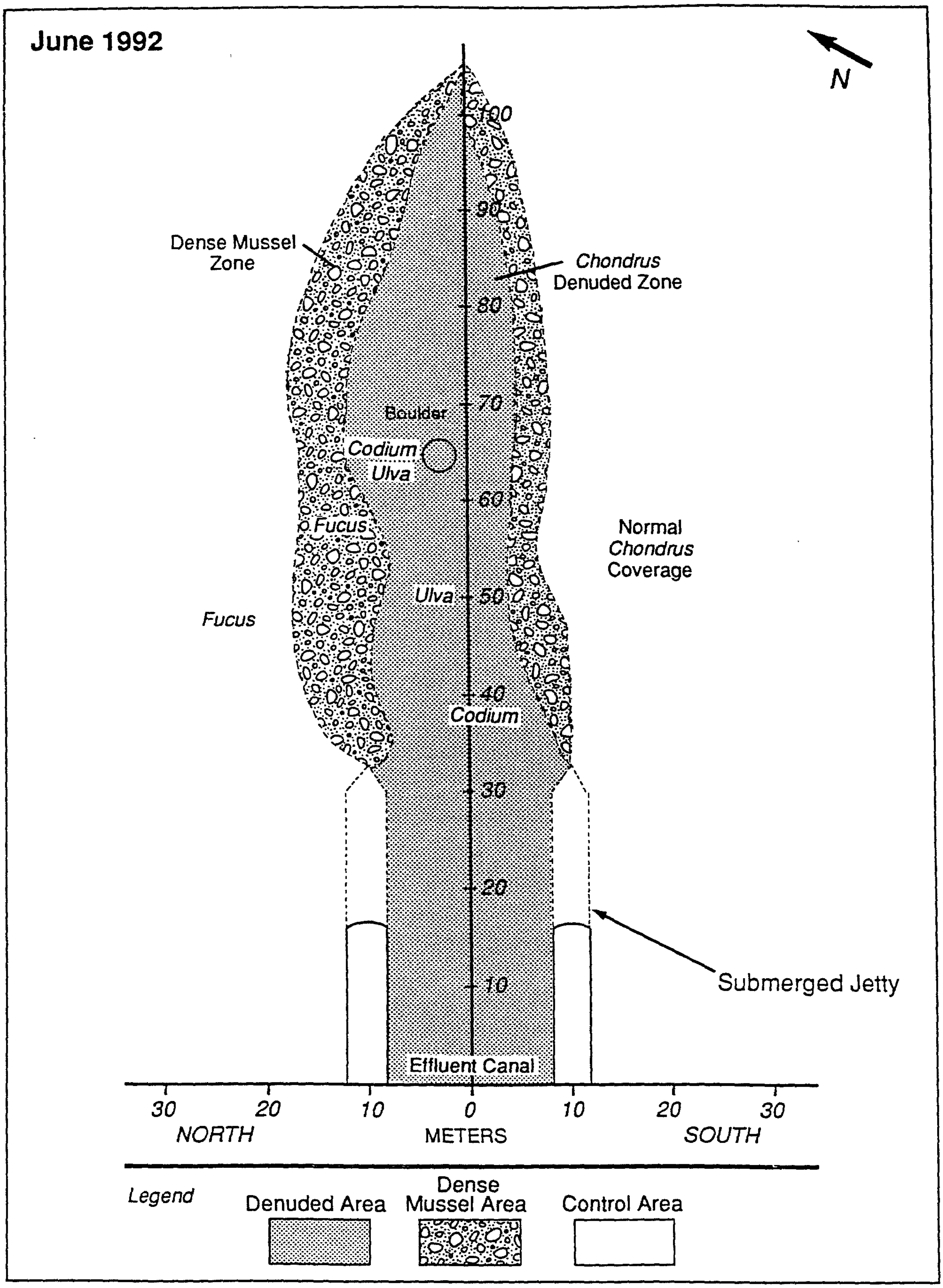


Figure 4. **Denuded *Chondrus* and Dense Mussel Zones Observed in June 1992. Mussels did cover the entire area but their pattern was excluded from the denuded zone.**

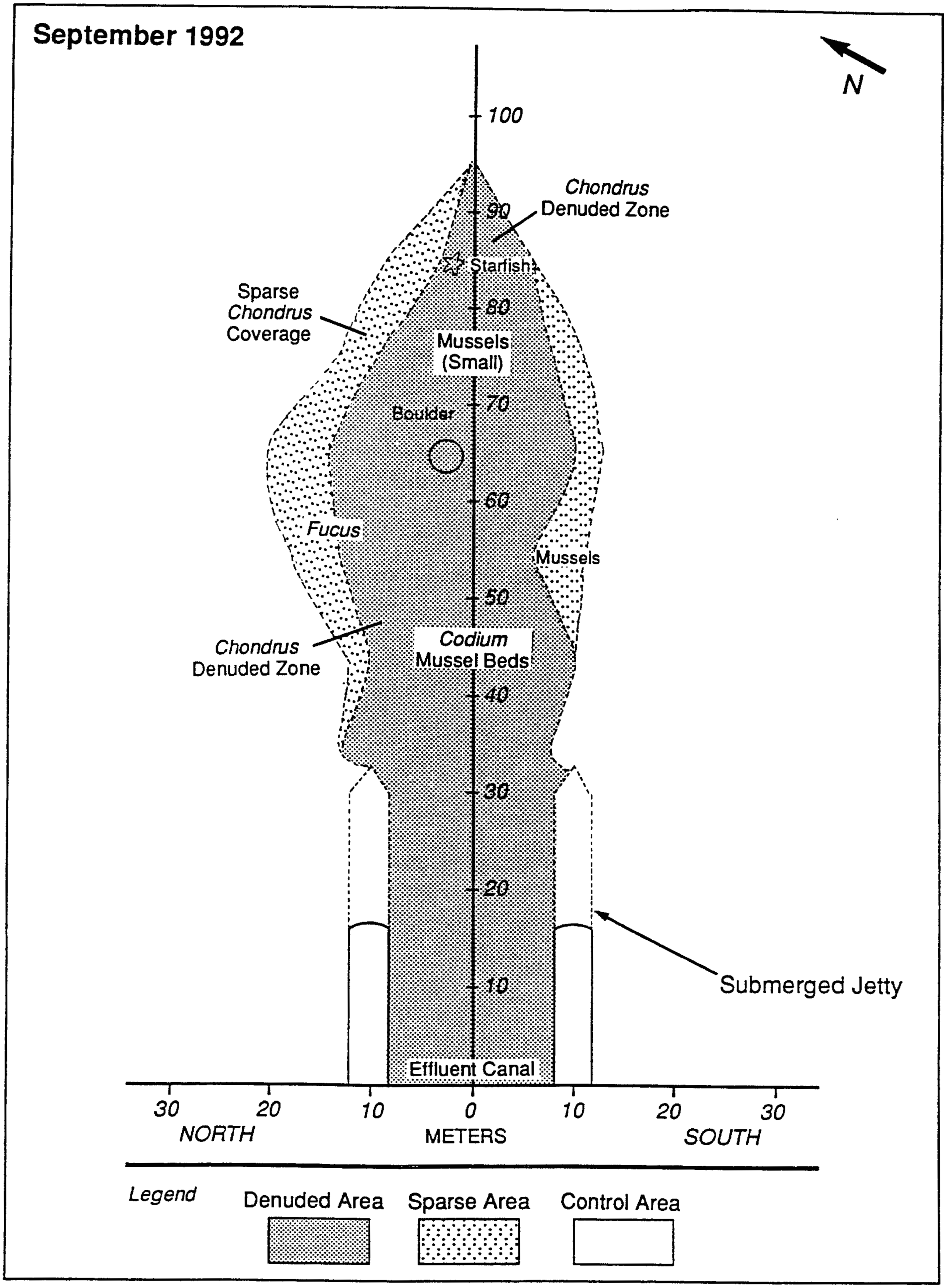


Figure 5. Denuded and Sparse *Chondrus* Zones Observed in September 1992.

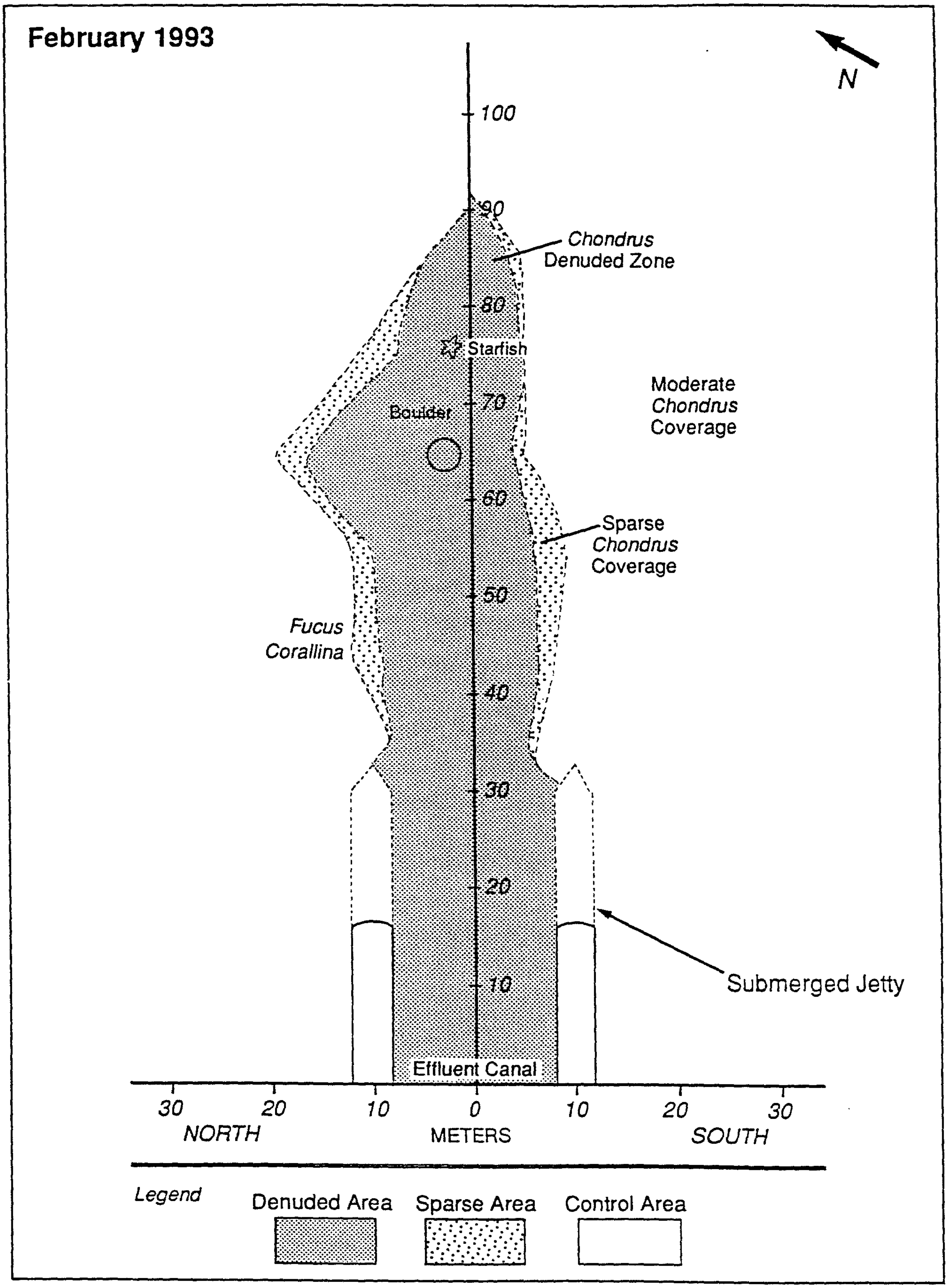


Figure 6. **Denuded and Sparse *Chondrus* Zones Observed in February 1993.**

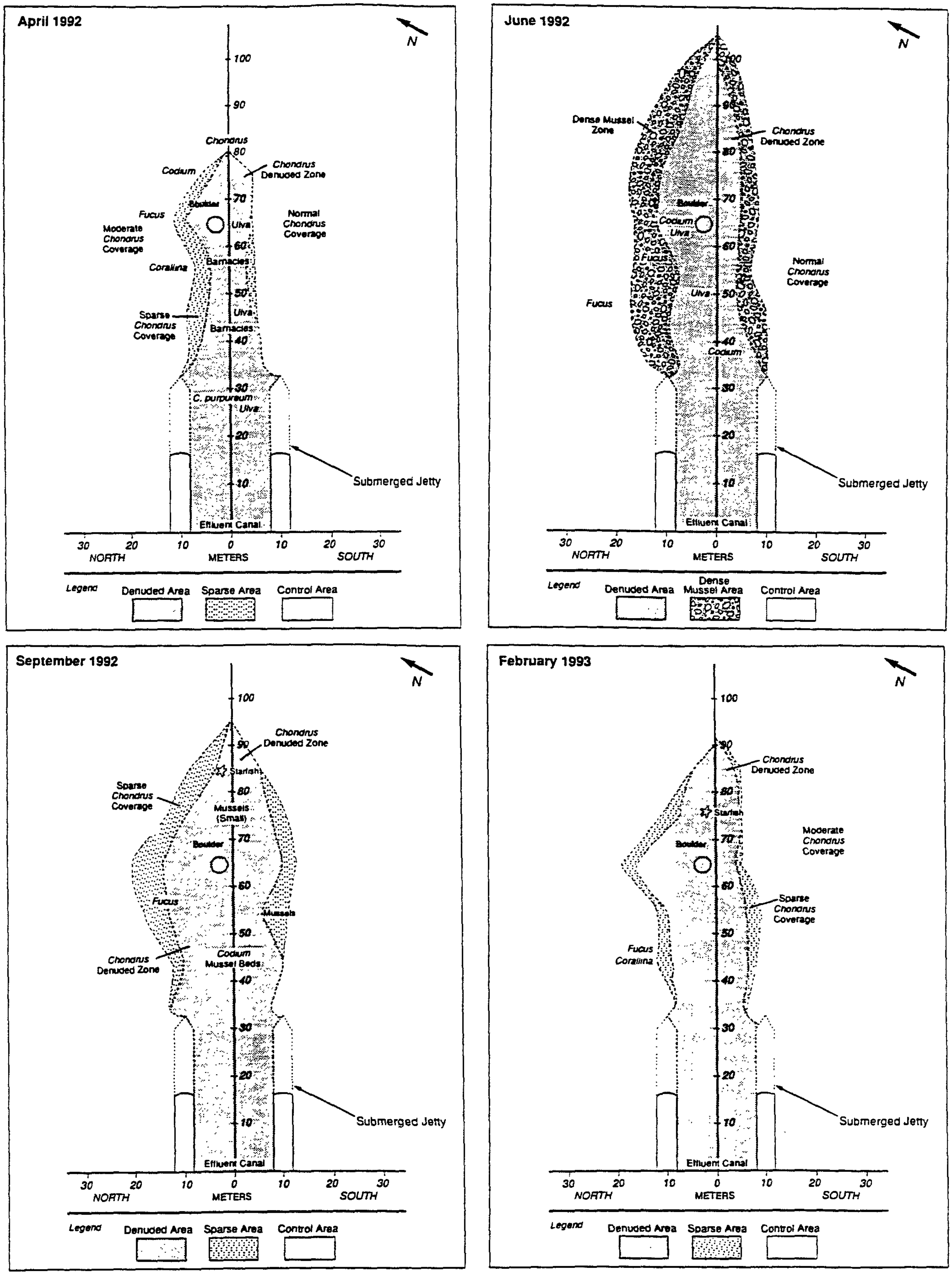


Figure 7. **Results of the 1992 Qualitative Transect Surveys of the PNPS Acute Impact Zone off the Discharge Canal taken in April, June, and September 1992 and February 1993.**

(SAIC) and the Massachusetts Division of Marine Fisheries dive teams, is plotted in each figure. This boulder serves as a visual fix for the proper placement of the transect line and ensures consistency among the surveys.

2.2.1 APRIL 1992 TRANSECT SURVEY

The extent of the denuded and sparse *Chondrus crispus* areas mapped on April 9, 1992, immediately offshore from PNPS is shown in Figure 3. The *Chondrus* denuded zone extended approximately 80 m offshore along the central transect line and was rather symmetrically distributed with an hourglass shape that was narrowest at the 55-m mark and bulging to its greatest extent to the north at the boulder at the 65-m mark. The denuded zone covered an area of 996 m^2 and was 17% smaller than in December 1991. In April 1992, rocks within the *Chondrus* denuded zone were covered by a thin layer of juvenile barnacles. Patches of *Ulva lactuca*, located primarily within 3 to 5 m of the central transect line, were also common in the denuded zone. The divers classified no area as a stunted zone but did define a sparse zone with an area of about 154 m^2 that was 32% smaller than the combined sparse and stunted zones measured during the December 1991 survey.

2.2.2 JUNE 1992 TRANSECT SURVEY

Results of the divers' survey for June 16, 1992, are mapped in Figure 4. The denuded zone extended to 105 m along the transect line, 25 m more than in April, and was slightly asymmetrically distributed around the transect line with more area denuded northwest of the line than southeast of the line. The area (1429 m^2) of the denuded zone was 43% larger than in April 1992 and 13% larger than in June 1991. An extremely dense settlement of juvenile blue mussels (*Mytilis edulis*), each approximately 0.5 cm long, covered the denuded zone (note that the mussel pattern was excluded from the denuded zone in Figure 4) and made delineation of a stunted or sparse zone impossible. The area of the dense mussel zone that extended beyond the *Chondrus* denuded area (701 m^2) was 4.55 times as large as the sparse zone measured in April 1992. The total affected area (2130 m^2) was 85% larger than in April 1992 and 52% larger than in June 1991.

2.2.3 SEPTEMBER 1992 TRANSECT SURVEY

Figure 5 shows the results of the transect survey conducted on September 29, 1992. The denuded zone extended to the 95-m mark on the transect line. The asymmetry of the denuded zone around the transect line was less pronounced than in the June survey and similar to that seen in the October 1991 survey. The greatest lateral extent of the denuded zone was 14 m from the transect line at the 65-m mark. The area (1569 m^2) of the denuded zone was 10% larger than that found in June.

Within the discharge canal, approximately 90% of the rock surfaces was covered by a purple, fibrous alga, probably *Cystoclonium purpureum*, and a green, thin-bladed alga, probably *Gracilaria*. Several fish (striped bass and tautog) were seen in the canal. At the 45-m mark on the transect line, *Codium*, *Cystoclonium purpureum*, and intact mats of living mussels, *Mytilus edulis*, occupied the area within 10 m of the central transect line. Further along the transect line, mussel beds at the 55-m, 65-m, and 75-m marks showed increasing signs of predation by the starfish *Asterias forbesi*. However, starfish were observed only at the 85-m mark. Many crabs were seen at the 65-m mark. From the 55-m mark and beyond, the *Chondrus* plants within the "sparse" area were tattered from being covered by mussels earlier in the season. As seen in past surveys, algal density and species richness were greater south of the transect line than north. South of the affected area, the denuded zone was clearly delineated by an abrupt increase in the number of healthy *Chondrus* plants approximately 6 - 8 m from the central transect line. Algal density beyond the southern boundary of the *Chondrus* denuded zone was much greater than that observed beyond the northern boundary. *Corallina* was not as plentiful as in previous surveys and *Codium* density had increased, especially at the 35-m and 45-m marks on the transect line. No *Laminaria* was seen in the area.

Chondrus plants in the sparse region (339 m^2) had been damaged from burial by a heavy settlement of mussels earlier in the season. This damage prevented the divers from being able to distinguish a zone of *Chondrus* that was stunted due to direct effects of thermal effluent from the power plant. The sparse zone was asymmetrically distributed with 67% (227 m^2) of the area north of the transect line. To the north, the sparse zone followed the distinct bulge of the denuded area and extended 20 m from the transect line at the 65-m mark; on the southern side, the sparse zone appeared as a 3 to 5 m wide band from the 45-m to 85-m mark on the transect line.

2.2.4 FEBRUARY 1993 TRANSECT SURVEY

The results of the 1992 winter dive, performed on February 10, 1993, are mapped in Figure 6. The marked increase in algal density and richness usually seen south of the denuded area boundary was not as noticeable during the February dive. Other notable changes had occurred in the dive area since the September visit. There was significant erosion and change in the topography of the boat ramp, several very large rocks (3-4 feet in diameter) belonging to the southern jetty had moved, there was less algal coverage throughout the area, all mussel shell debris had been washed away, and the bottom between larger rocks was covered only with pebbles and stones rather than with sandy or silty sediments. All of these changes probably were caused by the intense 3-day northeaster that blew from Dec. 11 to 14.

The denuded zone extended out to the 91-m mark on the transect line. The area (1315 m^2) of the denuded zone was 16% less than in the September survey and 8% less than in June. The asymmetry of the denuded zone around the transect line was more pronounced than in June or September with 58% of the area north of the central transect line and 42% of the area to the south. A prominent bulge of the denuded zone extended 16 m to the northwest at the 65-m mark.

Algal coverage (20%) within the discharge canal was significantly less than observed during previous 1992 surveys. At the 45-m mark, small patches of purple algae (probably *Cystoclonium purpureum*) were seen within 3 to 4 meters of the central transect line; *Corallina* and *Fucus* were present to the north beyond the sparse zone. At the 55-m mark, the denuded area consisted mostly of bare rock inhabited by a modest population of snails. The only mussels (*Mytilus edulis*) seen during this survey were south of the boulder at the 65-m mark; these were young individuals, lying on the seafloor between rocks and covered with a thin layer of pebbles. Some starfish were seen at the 75-m mark. No *Laminaria*, fish, or crabs were observed in the study area.

The area inhabited by sparsely distributed *Chondrus* plants was about 177 m^2; this was 48% smaller than in September. The sparse zone occurred as a narrow band along nearly the entire edge of the denuded zone on both sides of the transect line; to the northwest the sparse area followed the distinct bulge of the denuded zone at the level of the boulder and extended to 19 m away from the transect line.

The denuded area of 1315 m^2 was slightly greater than seen in the majority of earlier winter (December) surveys conducted in years (1983, 1985, 1989, 1990, and 1991) when the power plant was in full operation. The range in size of the denuded zones in December of 1983, 1989, 1990, and 1991 was 1200 m^2 to 1270 m^2, only 45 to 115 m^2 smaller than that measured in February 1993. The exception was 1985 which showed a relatively much smaller denuded area (925 m^2) in December. However, the total affected area (1491 m^2) in February 1993 was well within the range (1220 to 1830 m^2) seen in prior December surveys when the plant was in full operation and was very close to the size observed in 1990 and 1991.

2.3 DISCUSSION

The pattern of the *Chondrus crispus* denuded zone in the region extending to 100 m beyond the discharge canal is readily apparent to SCUBA divers and is easily mapped and measured for the qualitative transect survey. The stunted and sparse zones are somewhat less obvious and in June 1992 were totally obliterated by an enormous mat of blue mussels. This dense mat of mussels was similar to that seen in the June 1990 transect survey, although the individuals were smaller (0.5 cm compared to 1 to 2 cm long) suggesting that the current survey occurred closer to the time of settlement than the 1990 survey. In both 1990 and 1992 the area of the denuded zone in June was larger than it had been in the spring, a trend opposite that seen in most other years, suggesting that the high density of mussel juveniles adversely affected the early summer growth of *Chondrus*. In addition, it was clearly seen in the September dive that the *Chondrus* plants in the sparse area had been damaged from burial by the extensive mussel settlement. For 1992 surveys, the areas of the denuded zones and the total affected area (this included the dense mussel zone for June 1992) were similar to those seen in past years when the power plant was in full or nearly full operation.

3.0 IMPACT OF EFFLUENT DISCHARGE AT PNPS ON ALGAL DISTRIBUTION

The presence of hundreds of square meters of seafloor where *Chondrus crispus* is absent provides evidence that the nearfield discharge area is intensely affected by the bottom scouring produced by the outflow of the cooling water. In order to study this acutely impacted area, a qualitative diver transect study was designed to provide maps showing the effects of the thermal effluent on the surrounding algal communities. SCUBA divers perform quarterly transect surveys to measure the extent of denudation and other reductions in size or density of the algal flora in the nearfield discharge area. The focus of these studies is the commercially important red alga *Chondrus crispus* (Irish Moss), a species common to western Cape Cod Bay. Divers swim along a measured transect line in the discharge area and note the boundaries of the denuded, stunted or sparse, and normal *Chondrus* zones. Variations in the size of these zones are recorded over time as a means of determining the area most severely affected by PNPS operations.

3.1 BACKGROUND

Operational conditions at the PNPS have historically provided an opportunity to assess long-term trends associated with the impact on the benthic community. Plant operations have included years of nearly full operation as well as times when there were complete shutdowns, sometimes for prolonged periods. The longest outage in the history of the plant began in April 1986 and continued until March 1989. During this period the benthic community associated with the effluent canal and nearby areas immediately offshore experienced reduced current velocity as the use of circulating pumps was restricted to one or none (Figure 7). In addition, the discharge water remained at ambient temperature. As a consequence, the benthic community normally affected by these effluent parameters recovered, so that by 1988 there was essentially no difference between the control stations and the areas near the discharge canal.

Studies conducted after the power plant returned to full operation, with the resumption of electrical generation and the operation of either one or both circulating pumps, originally were designed to assess the impact of plant operation on a benthic environment that had returned to near ambient conditions. Quantitative faunal and algal monitoring studies and qualitative transect surveys were conducted through 1991. For the 1992 study season the monitoring program was restricted to seasonal qualitative surveys of the discharge area; community studies of the benthic algae and fauna were discontinued.

The percent of time that PNPS operated in 1992 was very high. Figure 7 depicts the monthly maximum dependable capacity (MDC) factor and circulating water pump operation of PNPS since 1983. The MDC is a measure of reactor output that approximates thermal loading to the marine environment. A maximum MDC value of 100% represents the highest allowable change in ambient temperature for water discharge to Cape Cod Bay (18°CΔT). In 1992, the monthly maximum dependable capacity factor was greater than 94% for 7 months and above 50% for four of the remaining months. These high monthly capacity factors resulted in the annual capacity factor of 80.6% for 1992, an amount exceeded previously only in 1979 and 1985. In addition, both pumps were in operation for the 11-month period from December 1991 through October 1992 and again in December 1992. In 1992, the plant experienced only a mini-outage from the end of March until mid-April and a mid-cycle outage in November.

3.2 QUALITATIVE TRANSECT SURVEYS: 1983-1992

Results of the qualitative transect surveys from 1983 through 1992 are summarized in Figure 8. The total acute impacted area (denuded, sparse, and including the dense mussel zone seen in June, 1992) is plotted as well as the area of the denuded zone only and the monthly PNPS capacity factor (MDC). The difference between the denuded and total acute impact zones represents the sparse zone (and included the dense mussel zone in June 1992). A lag-time in recovery response by the acute impact zone to the 1984 PNPS power outage was reported in Semi-Annual Report No. 27 (BECO, 1986). Evidence of this slow recovery included a decrease in the area of the total acute impact zone that began in mid-1984 (5 months after the cessation of power plant operations) and continued through mid-1985. Between

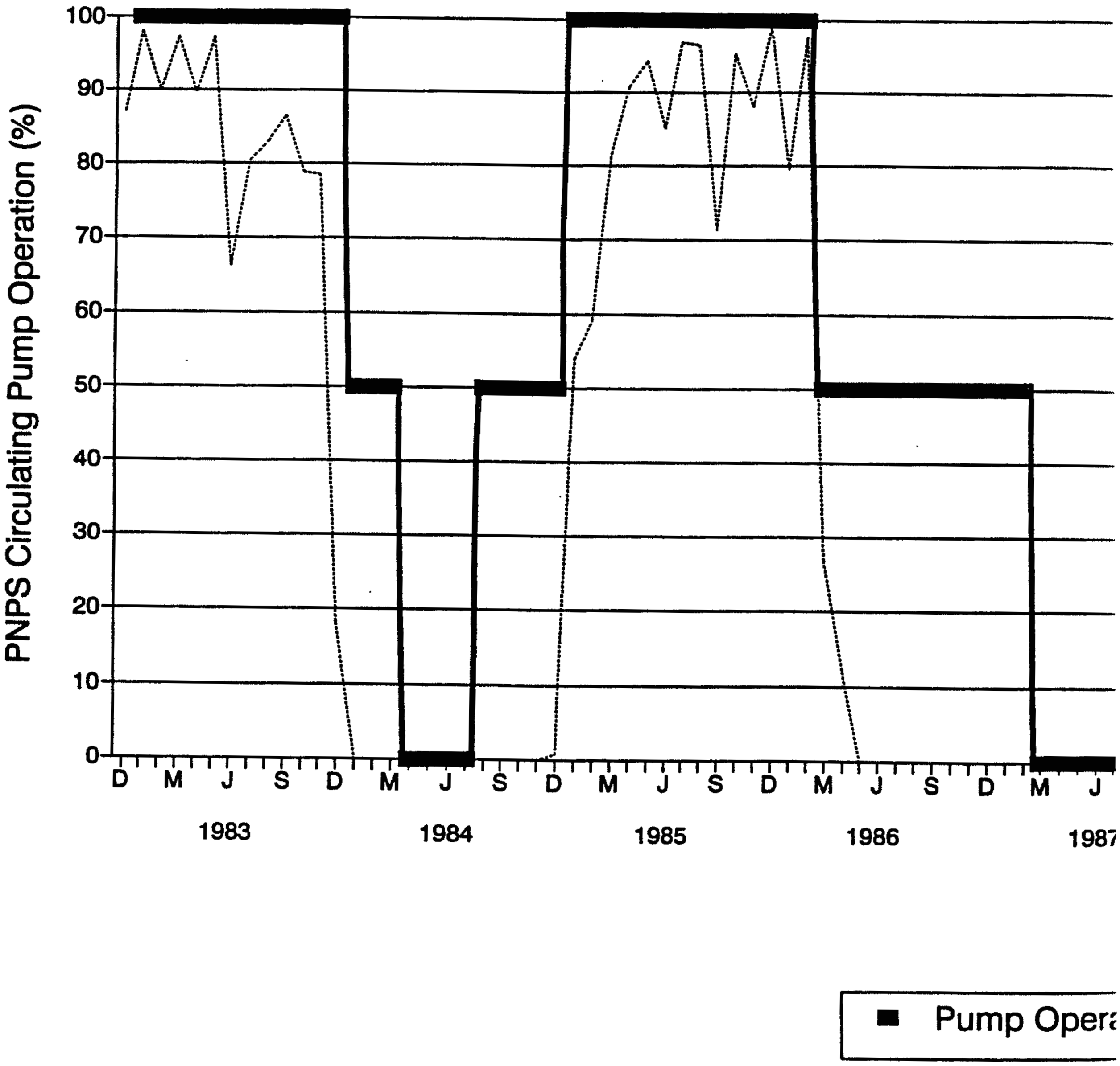
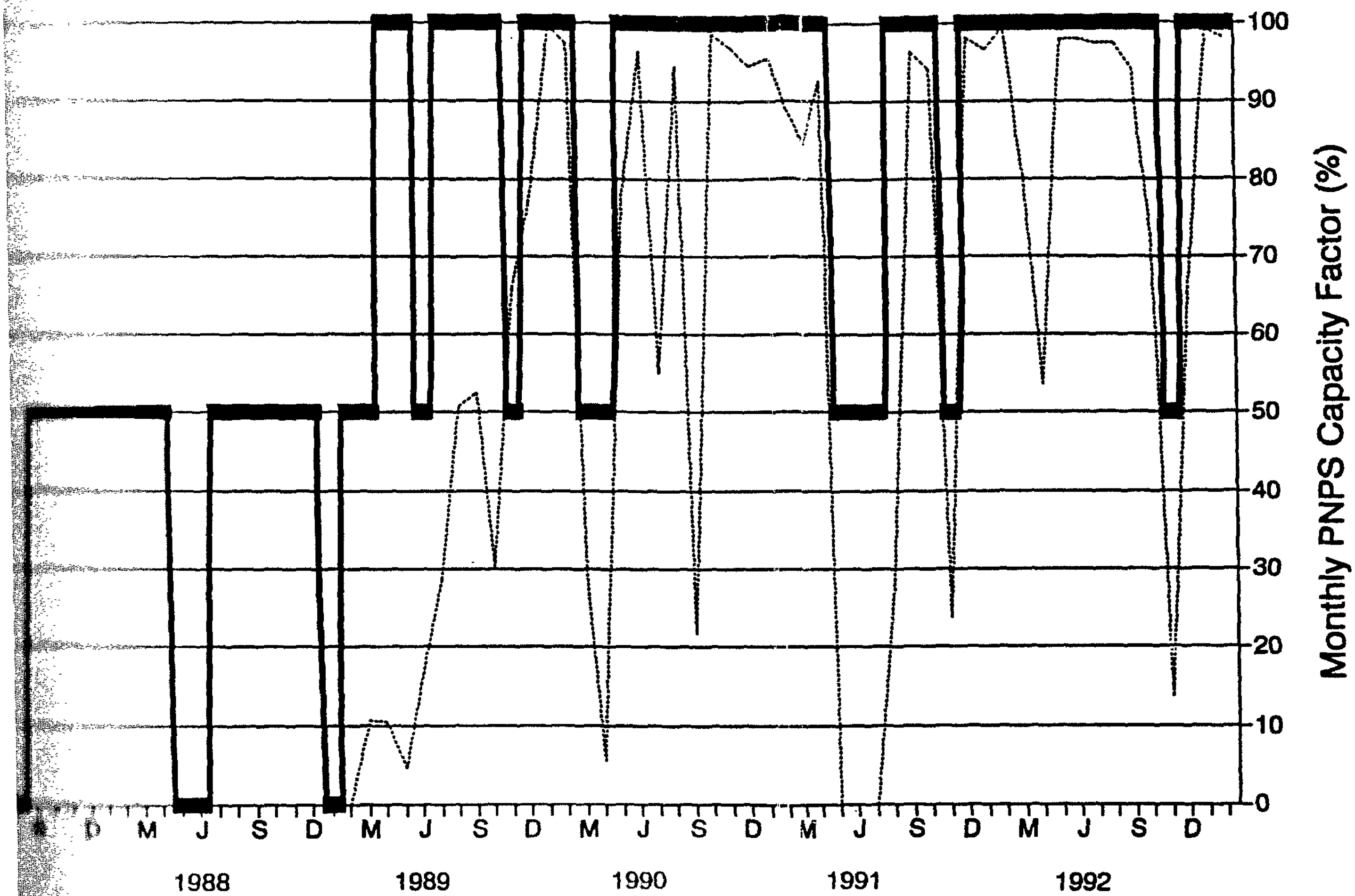


Figure 8. **Monthly PNPS Capacity Factor (dashed li at 50% = 1 pump; at 0% = 0 pumps) Pl**



MDC

and Circulating Pump Activity (black bars at 100% = 2 pumps;
for the Period 1983 Through 1992.

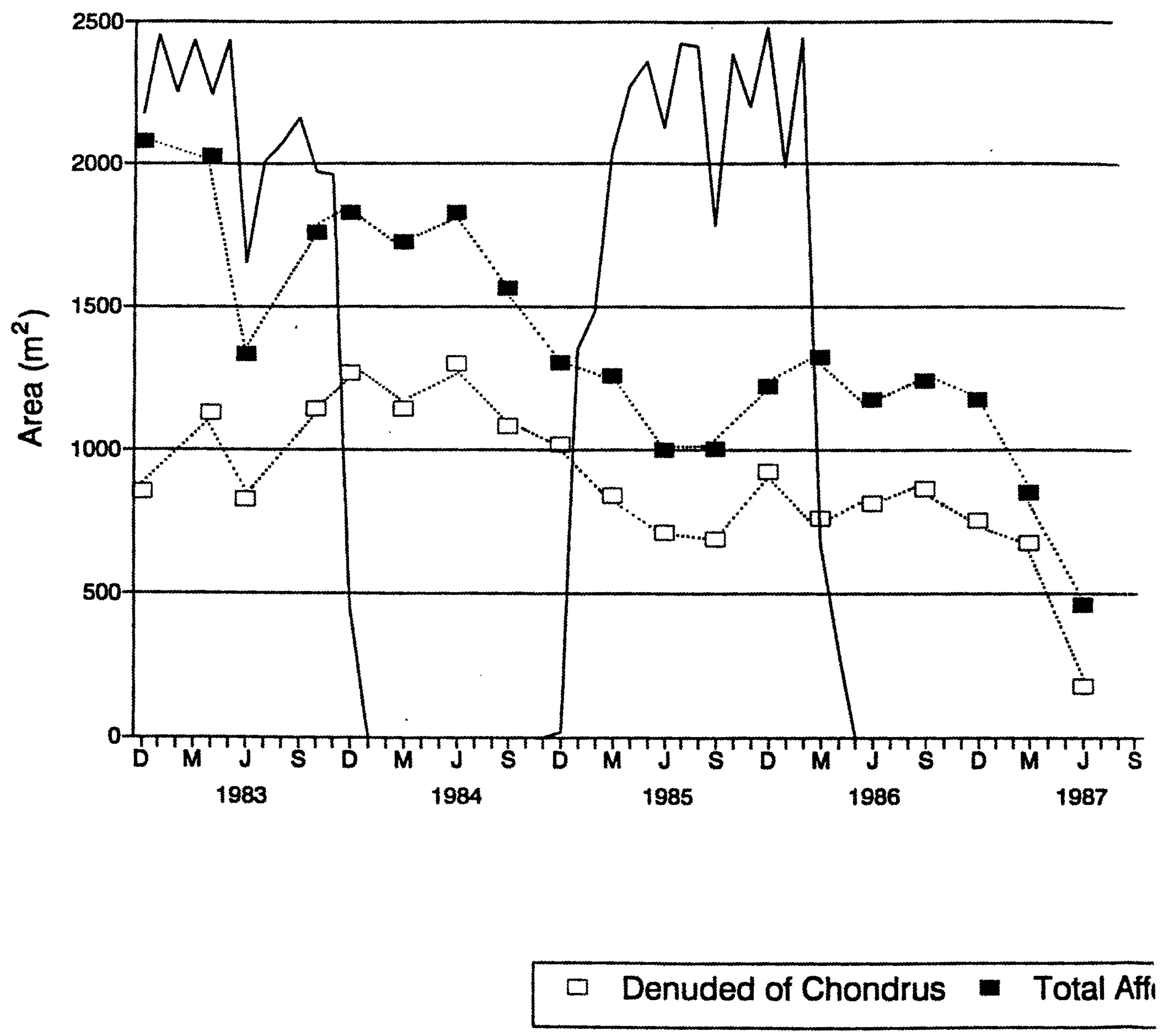
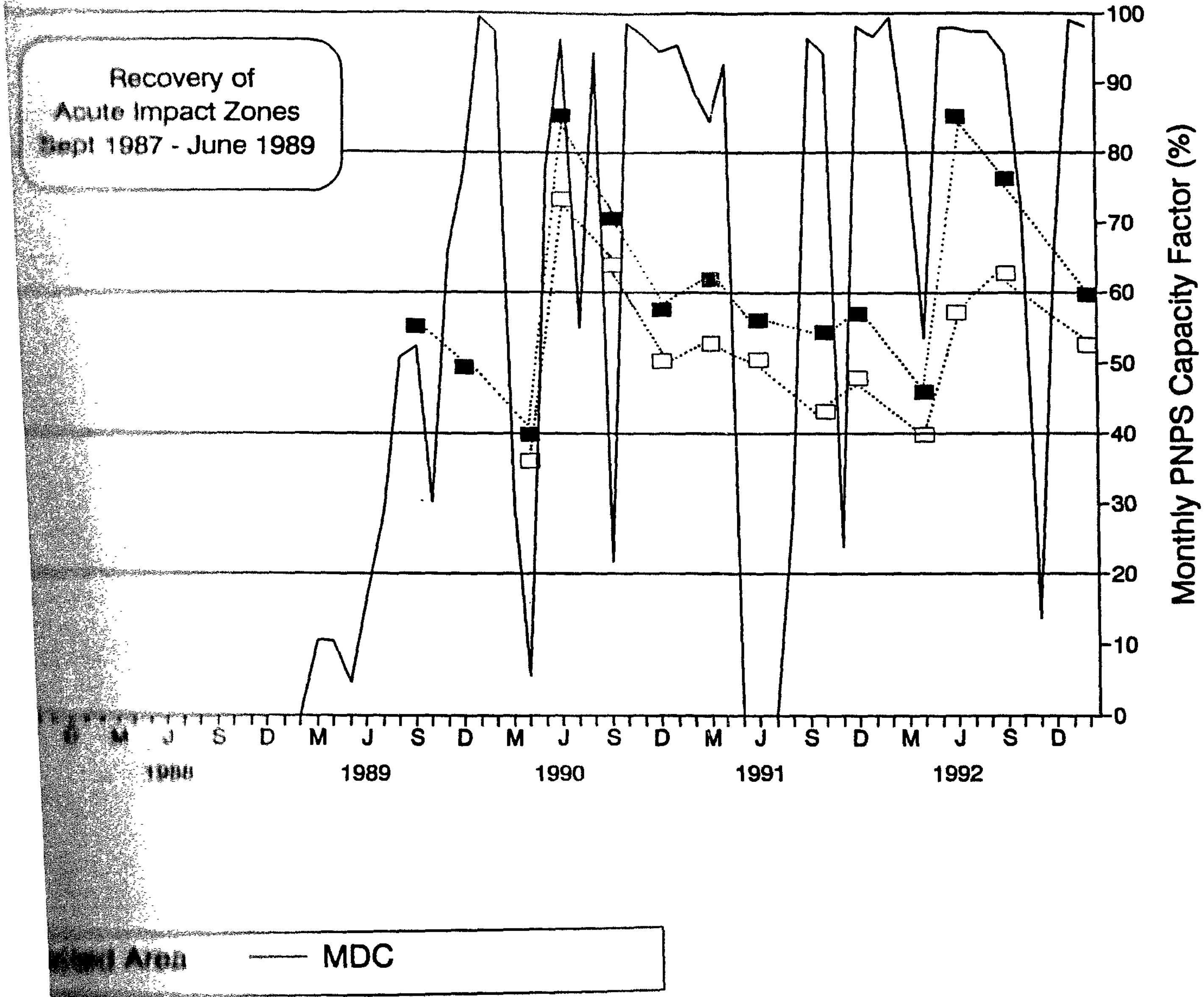


Figure 9. **Area of the Denuded and Totally Affected Zones Monthly PNPS Capacity Factor (MDC). No area 1989 because definitive demarcations of denuded**



of the PNPS Effluent Canal Plotted with the
were made from September 1987 through June
zones were absent.

December 1984 and December 1985, the total affected area was the smallest recorded between 1983 and 1986, indicating a delay in recovery of this area in response to the absence of thermal discharge in 1984. This phenomenon reversed itself under normal PNPS operating conditions, so that only 6 to 9 months after the resumption of thermal effluent discharge the size of the acute impact zone began to increase between September and December 1985. These results confirmed a delay period of about 6-9 months between the causal factor (cessation or resumption of thermal effluent discharge) and associated response (decrease or increase in size of the acute impact zone).

In 1987, increased recolonization of the denuded and stunted zones by *Chondrus crispus* made zone boundaries difficult to distinguish (no areal differences could be discerned from September 1987 through June 1989). As in summer 1984, the considerable decrease of the denuded area of the acute impact zone between December 1986 to June 1987 was primarily the result of the shutdown of the circulating water pumps from late March to early September (BECO, 1988). Apparently, water current scouring is a greater stress to algal colonization than increased water temperature. Scouring denudes the substratum, whereas elevated temperature results in stunted growth (Bridges and Anderson, 1984).

In 1988, circulating water pump activity was low, resulting in few thermal loading and scouring effects. The 1988 transect surveys showed such an increase in recolonization of the formerly denuded and stunted zones by *Chondrus*, in response to the continuing outage, that the divers were unable to detect boundaries of these zones, and no area measurements could be made. In March and June 1989, divers were still unable to detect boundaries of the denuded or stunted zones, and again no area measurements were made (BECO, 1990). In September and December 1989, presumably in response to increased PNPS operations and the resultant scouring of the acute impact zone, boundaries began to be redefined and area measurements were made of the total impact zone.

During 1990, boundaries between the stunted and denuded zones became even more clearly defined and areal measurements of both zones were made. The areas of the denuded and total acute impact zones in June 1990 were the largest seen since 1983 (BECO, 1991). The dramatic increase in total affected area that occurred between April and June 1990 had not been seen before in the 1983-1990 period. The typical pattern seen prior to 1990 was that during the spring, with warmer temperatures and increased sunlight, algal growth flourishes, and the impact area declines even in years when the power plant is operating at high capacity. The pattern seen in 1990 appeared to be anomalous.

In 1991, the boundaries of the acute impact zone remained well-defined, except that in June there was no true stunted zone but only an area described by the divers as "sparse", that is, where the algal plants grew normally but were thinly distributed. From March to June, the total affected area and the

Chondrus denuded zone decreased in area, a return to the typical pattern seen before 1990 (BECO, 1992). This decrease in area continued through the October survey, perhaps aided by the May through July power plant outage. There was a slight increase in affected area in December.

During 1992, the divers were unable to discern a region of *Chondrus* that was stunted owing to the effects of the thermal effluent. Rather, they noted zones containing normal looking but sparsely distributed *Chondrus* plants during all surveys, except for June. An enormous set of mussel larvae that had reached 0.5 cm in length by June, totally obliterated the boundary between the denuded and sparse areas. Corresponding with results seen in 1990, the areas of the denuded and total acute impact zones in June 1992 were larger than any seen (except for 1990) since 1983 and the dramatic increase in total affected area that occurred between April and June in 1990 happened again in 1992. Thus, the pattern seen in 1990 should no longer be considered as anomalous but may be related to oceanographic conditions that lead to a large settlement of mussel larvae and consequent damage to the *Chondrus* plants.

4.0 CONCLUSIONS

- The size of the denuded and total affected areas of the acutely impacted region in 1992 was similar to that observed during earlier times of full power plant operation.

- The increase in size of the denuded and total affected zones from April to June followed a pattern also seen in 1990. This variation from the more usual pattern of a decrease in denuded area when sunlight and warmth permits the algae to flourish, may be associated with the enormous mussel settlement that occurred in both 1990 and 1992.

- In February, the size of the denuded area was slightly greater than seen in the majority of earlier December surveys performed when the power plant was in full operation. The exception was 1985 which showed a relatively small denuded area in December. The total affected area was well within the range of that seen in prior December surveys.

5.0 LITERATURE CITED

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ICHTHYOPLANKTON ENTRAINMENT MONITORING

AT PILGRIM NUCLEAR POWER STATION

JANUARY-DECEMBER 1992

Volume 1 of 2

(Results)

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

April 15, 1993

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*Available upon request.

SECTION I

EXECUTIVE SUMMARY

PNPS ichthyoplankton entrainment sampling was completed twice per month during January, February, October, November, and December, weekly from March through September.

Numerical dominants among the 36 species represented in the collections included American plaice, sand lance, and rock gunnel during winter-early spring; cunner, mackerel, sand lance, and rockling during late spring-early summer; and rockling during late summer-autumn.

Comparisons between 1992 monthly mean densities per 100 m^3 of water and those recorded over the 1975-1991 period suggest that rockling eggs were uncommon in May and June, larval flounder were uncommon in April, and larval seasnail were uncommon in June. In contrast, mackerel eggs continue to be abundant in June. Larval sand lance were also relatively abundant in February and May as were larval rock gunnel in April.

No unusually high densities warranting contingency sampling were observed in 1992 and no lobster larvae were obtained.

SECTION II

INTRODUCTION

This report summarizes results of ichthyoplankton entrainment sampling conducted at the Pilgrim Nuclear Power Station (PNPS) discharge canal on a regular basis from January through December 1992. Work was carried out by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 69010 in compliance with environmental monitoring and reporting requirements of the PNPS NPDES Permit (U.S. Environmental Protection Agency and Massachusetts Division of Water Pollution Control). In an effort to condense the volume of material presented in this report, details of interest to some readers may have been omitted. Any questions or requests for additional information may be directed to Marine Research, Inc., Falmouth, Massachusetts, through BECo.

SECTION III

METHODS AND MATERIALS

Entrainment sampling at PNPS was scheduled twice per month during January, February, October, November, December, and weekly from March-September. With the exception of those taken on April 7 and in November, all collections were made with both circulating water system pumps in service. One CWS pump was in operation on April 7 and in November while the plant was down for maintenance. One scheduled sampling event was missed in late July due to failure of the sampling rig.

All samples were collected in triplicate from rigging mounted approximately 30 meters from the headwall of the discharge canal (Figure 1), at low tide during daylight hours. A 0.333-mm mesh, 60-cm diameter plankton net affixed to this rigging was streamed in the canal for 8 to 12 minutes depending on the abundance of plankton and detritus. In each case, a minimum of 100 m^3 of water was sampled. Exact filtration volumes were calculated using a General Oceanics Model 2030R digital flowmeter mounted in the mouth of the net.

All samples were preserved in 10% Formalin-seawater solutions and returned to the laboratory for microscopic analysis. A detailed description of the analytical procedures may be found in MRI (1988).*

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*Marine Research, Inc. 1988. Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January-December 1987. III.C.1-6-10. In: Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-annual Report No. 31. Boston Edison Company.

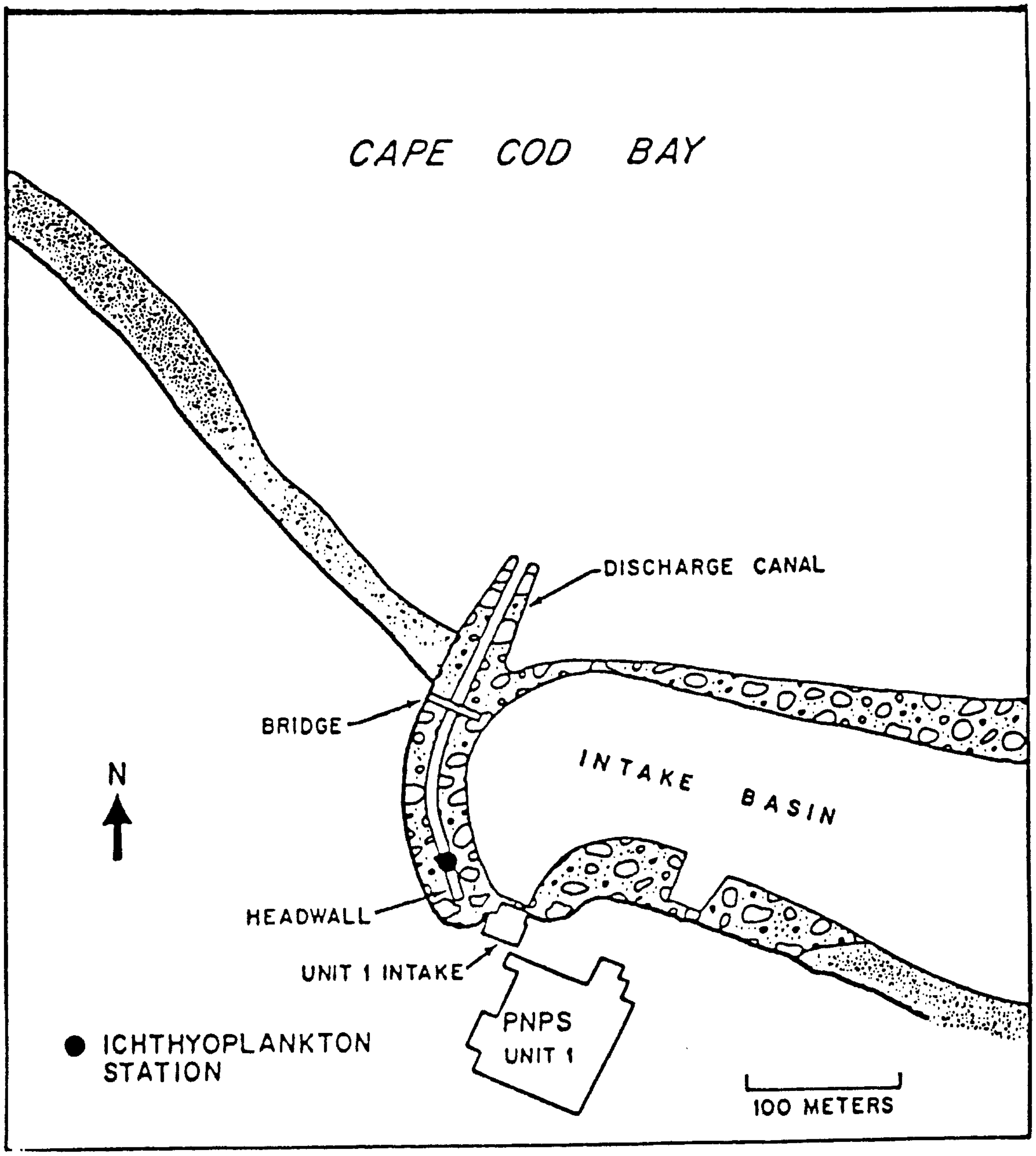


Figure 1. Entrainment sampling station in PNPS discharge canal.

When the Cape Cod Bay ichthyoplankton study was completed in 1976, a contingency sampling plan was added to the entrainment monitoring program. This plan was designed to be implemented if eggs or larvae of any dominant species proved to be "unusually abundant" in the PNPS discharge samples. The goal of this sampling plan was to determine whether circumstances in the vicinity of Rocky Point, attributable to PNPS operation, were causing an abnormally large percentage of ichthyoplankton populations there to be entrained or, alternatively, whether high entrainment levels simply were a reflection of unusually high population levels in Cape Cod Bay. "Unusually abundant" was defined as any mean density, calculated over three replicates, which was found to be 50% greater than the highest mean density observed during the same month from 1975 through 1991.

The contingency sampling plan consists of taking additional sets of triplicates from the PNPS discharge on subsequent dates to monitor the temporal extent of the unusual density. An optional offshore sampling regime was also established to study the spatial distribution of the species in question. The offshore contingency program consists of single, oblique tows at each of 13 stations (Figure 2) on both rising and falling tides for a total of 26 samples. Any contingency sampling requires authorization from Boston Edison Company.

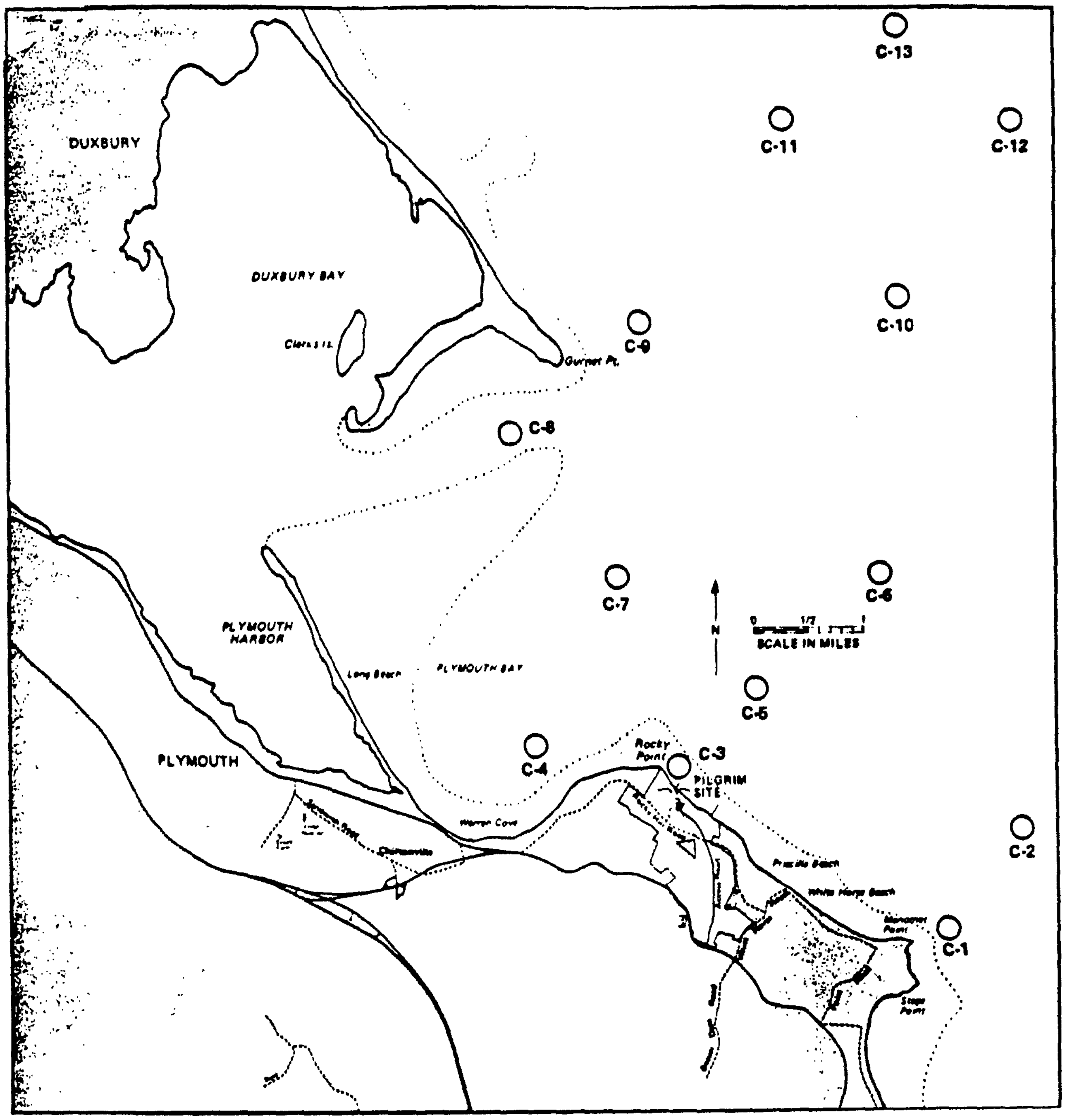


Figure 2. Location of entrainment contingency plan sampling stations, C-1 through C-13.

SECTION IV

RESULTS AND DISCUSSION

A. Ichthyoplankton Entrained - 1992

Population densities per 100 m^3 of water for each species are listed by date, station, and replicate for 1992 in Appendix A (available upon request). Table 1 lists all species represented in the 1992 collections, indicates the months eggs and/or larvae of each species were found and, for the more common species, the months of peak abundance.

Ichthyoplankton collections are summarized below within the three primary spawning seasons observed in Cape Cod Bay: winter-early spring, late spring-early summer, and late summer-autumn. Figure 3 shows the dominant species of eggs and larvae and their percent contribution within each season for 1992.

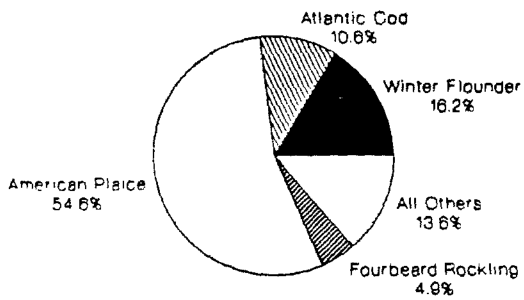
Winter-early spring spawners (December-April)

The beginning of this spawning season is sampled at the end of the calendar year. The two December 1992 collections (6 samples) contained 13 cod (*Gadus morhua*) and one pollock egg (*Pollachius virens*) along with 11 Atlantic herring (*Clupea harengus*), three rock gunnel (*Pholis gunnellus*), two sand lance (*Ammodytes* sp.), and one cod larva. These counts produced monthly mean densities of 1.4 and 0.2 for cod and pollock as well as 1.5, 0.4, 0.4, and 0.1 for herring, sand lance, rock gunnel, and cod, respectively. The number of species found in the earlier January-April collections

Figure 3. Dominant species of fish eggs and larvae found in PNPS ichthyoplankton samples by season. Percent of total and summed monthly means for all species are also shown.

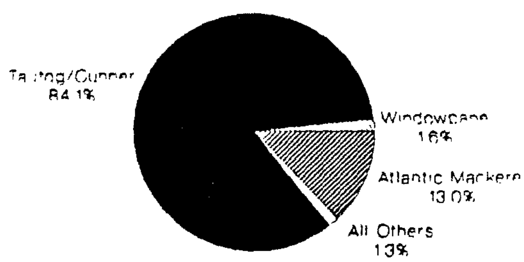
Eggs

Winter-Early Spring Season
December-April



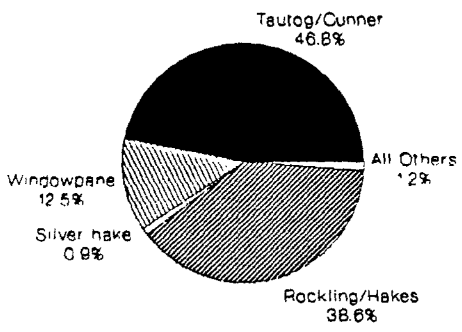
Sum of monthly means = 29.21

Late Spring-Early Summer Season
May-July



Sum of monthly means = 4316.86

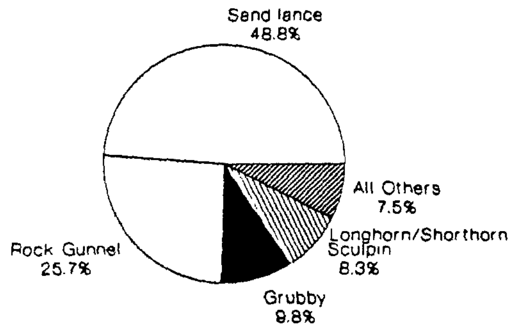
Late Summer-Autumn Season
August-November



Sum of monthly means = 361.75

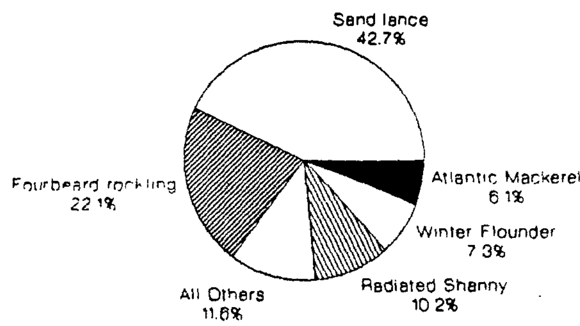
Larvae

Winter-Early Spring Season
December-April



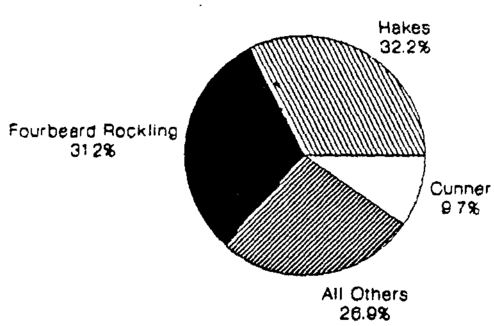
Sum of monthly means = 217.72

Late Spring-Early Summer Season
May-July



Sum of monthly means = 225.39

Late Summer-Autumn
August-November



Sum of monthly means = 21.27

were four in January, increasing to eight in February, ten in March, and seventeen in April. Eggs are typically uncommon during the winter-early spring period since species spawning in the PNPS area during that time rely on a reproductive strategy involving demersal, adhesive eggs which are not generally subject to entrainment. Eggs were, in fact, absent in January while two cod eggs were taken in February (monthly mean = 0.3 per 100 m^3). March collections contained little more with a total of one American plaice (Hippoglossoides platessoides) and three winter flounder (Pleuronectes americanus) eggs. Over the month as a whole these counts represented 0.1 per 100 m^3 for plaice, 0.2 per 100 m^3 for flounder. Eggs were more common in April, seven species being represented. Numerical dominants included American plaice, winter flounder, yellowtail flounder (Pleuronectes ferrugineus), and windowpane (Scophthalmus aquosus). These four species represented 89% of the egg total with respective monthly mean densities of 16, 5, 2, and 2 per 100 m^3 of water.

Since they are demersal and adhesive, winter flounder eggs are not typically entrained at PNPS. Their numbers in PNPS samples are therefore not considered representative of numbers in the surrounding area. Those that were taken were probably dislodged from the bottom by currents or perhaps other fish.

The number of species represented by larvae typically increases with time during the winter-early spring period. In 1992 four species were recorded in January, eight were taken in both February and March, and 13 were taken in April. Sand lance, rock gunnel, and sculpin (Myoxocephalus spp.) were numerically dominant during the period. Sand lance first appeared in February when they represented 65% of the catch with a monthly mean of 12 larvae per 100 m^3. They represented 47 and 49% of the March and April totals with monthly means of 41 and 53 per 100 m^3 of water, respectively. Larval rock gunnel densities and relative contribution increased steadily during the period. Percent contribution and corresponding monthly mean densities per 100 m^3 were 21% and 0.1 in January, 12% and 2 in February, 23% and 20 in March, and 31% and 34 in April. Sculpin represented an additional 24, 15, 22, and 16% of the larval total during the four respective months. Densities amounted to 0.1 in January, 3 in February, 19 in March, and 17 per 100 m^3 in April. Three species of sculpin larvae were actually represented in the catch. Over the season as a whole the grubby (Myoxocephalus aenaeus) contributed 55% of all sculpin. This was followed by the shorthorn sculpin (M. scorpius) at 41% and the longhorn sculpin (M. octodecemspinosus) at 4%. Only the longhorn was represented in January; otherwise all three species were present each month.

Late spring-early summer (May-July)

May, June, and July collections encompass the late spring-summer season. A total of 20 species were taken in May, 21 were taken in June, dropping to 16 in July. Eggs accounted for 10, 12, and 9 species among these respectively, the labrids and Atlantic mackerel (Scomber scombrus) being numerically dominant. The labrids, assuming they accounted for most of the eggs in the

Labridae-Pleuronectes group, represented 49% of the May total, 63% of the June total, and 99% of the July total. Monthly mean densities steadily increased from 105 in May to 941 in June and 1584 per 100 m^3 in July. Mackerel eggs contributed 32, 33, and 0.01% to the May, June, July totals with monthly mean densities per 100 m^3 of 68, 494, and 0.2.

Late spring-early summer larval collections contained 12 species in May, 18 species in June, and 11 species in July. Numerical dominants included sand lance, radiated shanny (*Ulvaria subbifurcata*), fourbeard rockling (*Enchelyopus cimbrius*), winter flounder, and Atlantic mackerel. Sand lance contributed only to the May catch as their period of occurrence ended; with a monthly mean of 96 per 100 m^3 of water, they represented 67% of the May larval total. Radiated shanny contributed an additional 14% of total in May as well as 2% of the June total and 10% of the July total; monthly mean densities were 21, 2, and 0.5 per 100 m^3, respectively. Winter flounder larvae overlap the winter-early spring and late spring-early summer seasons. Their numbers peaked in May with a mean density of 16 per 100 m^3 which accounted for 11% of that month's total. They contributed only 0.8% to the June catch (mean = 0.6 per 100 m^3) and were absent in July. Fourbeard rockling and mackerel first appeared during the second week of June and accounted for 63 and 17% of the June total with monthly means of 49 and 13 per 100 m^3. In July both species were uncommon with monthly means below one per 100 m^3 of water and percent contribution values of 10 and 17, respectively.

Late summer-autumn spawners (August-November)

This is typically a season of decline in both numbers of species and numbers of individuals. Species counts for eggs declined steadily from 12 in August to three in November, and the larval species count declined from 11 in August to one in November. Numerical dominants included the labrids, rockling and hake (Urophycis spp.), and windowpane among the eggs; rockling, hake, and cunner among the larvae. Labrid eggs accounted for 50, 6, and 19% of the August, September, and October egg totals being absent in November. Respective monthly mean densities were 167, 2, and 0.4 per 100 m^3 of water. Rockling and hake combined represented 40% of the August catch, 19% of the September catch, and 27% of the October catch with monthly means of 134, 5, and 0.5 per 100 m^3. They too were absent in November. Windowpane eggs contributed 8% of total in August with a mean density of 28, 64% of total in September with a mean of 17, and 8% of total in October with a mean of 0.2 per 100 m^3; none were taken in November.

Larval collections were all quite light, monthly means ranging from 0 to 3 for rockling, 0 to 4 for hake, and 0 to 2 per 100 m^3 for cunner.

B. Multi-year Ichthyoplankton Comparisons

Table 2 presents a master species list for ichthyoplankton collected from the discharge canal at PNPS and indicates the years each species was taken from 1975 through 1992. The general period of occurrence within the year is also indicated for each species including the peak period for the numerical dominants. A total of 36 species was represented in the 1992 collections, just below the overall average of 38. No new species were added to the overall list in 1992.

Monthly mean densities per 100 m^3 of water were calculated for each of the 13 numerically dominant fish eggs or fish egg groups, those accounting for 99.3% of the 1992 egg total, as well as total eggs (all species combined) for each year from 1975 through 1992 (Appendix B, available upon request). To help compare values over the 18-year period, egg data were plotted in Figure 4. For this figure cod and pollock eggs were combined with the gadid-*Glyptocephalus* group, rockling and hake were combined with the *Enchelyopus*-*Urophycis*-*Peprilus* group, and labrids and yellowtail were combined with the labrid-*Pleuronectes* group. For each category shown, the highest monthly means obtained from 1975 through 1991 were joined by solid lines as were the lowest monthly means, and the area between was shaded, indicating the range of these values. Monthly mean values for 1992 were joined by a dashed line. Alongside each plot is a bar graph showing annual abundance indices for each year. These were generated by integrating the area under each annual curve using trapezoidal integration. Appendix B and Figure 5 contain corresponding data for the eleven numerically dominant species of fish larvae, those accounting for 93.4% of the 1992 catch, as well as total larvae (all species combined). Low values obtained for both eggs and larvae during April through August of 1984 and 1987 were flagged in these figures and omitted from the following discussion because exceptionally low values were common then, probably due to low through-plant water volumes (see Impact section).

Based on these data, egg densities for Atlantic menhaden (Brevoortia tyrannus), searobins (Prionotus spp.), the labrids, windowpane, and American plaice were well within the range of densities observed over previous years. Among larvae, this was also true for Atlantic herring, fourbeard rockling, sculpin, tautog, radiated shanny, and Atlantic mackerel. For the remaining numerical dominants, the following comments are offered:

1. Atlantic cod eggs have never been abundant in PNPS winter entrainment samples, the highest observed monthly mean being 3.4 per 100 m^3 of water (January 1981). Nevertheless, following four consecutive years in which they were uncommonly absent in February, cod eggs at least appeared that month in 1992 (0.3 per 100 m). However, they were missing from March 1992 collections; this happened previously only in 1990.

2. Fourbeard rockling eggs (combined with the Enchelyopus-Urophycis-Peprilus group which they dominate) were relatively uncommon in May and June. Monthly means in 1992 amounted to 9 per m^3 in May, 14 per 100 m^3 in June. These densities ranked below corresponding values for May and June of every other year except one (May 1982 = 4; June 1991 = 9 per 100 m^3).

3. Atlantic mackerel eggs have been abundant in PNPS June samples over the past four years (1988-1991) particularly during 1988, 1989, and 1990 (1013 to 2220 eggs per 100 m^3 of water). Densities in 1991 and 1992 were nearly identical, 473 and 494 per 100 m^3 respectively, representing a decline over the 1988-1990 period. In spite of this drop, mackerel eggs remain abundant compared with 1975-1987 when means ranged from 5 (1976) to 277 (1986) per 100 m^3. The relatively high overall abundance value for 1985 was due to high egg counts in May. June densities of mackerel larvae have been variable over the same period ranging from 6 to 200 per 100 m^3. It is noteworthy however that 1991 (200 per 100 m^3) and 1989 (137 per 100 m^3) rank second and third among all June values.

4. Larval sand lance were relatively common throughout their period of occurrence in 1992 but were particularly so in February and May. With mean densities of 12 and 96 per 100 m^3, February and May ranked second and first, respectively, compared with corresponding months in past years. In February 1985 a density of 35 per 100 m^3 was recorded, ranking first for that month. The previous high May value was 80 per 100 m^3 in 1978.

5. Larval rock gunnel were numerous in April (34 per 100 m^3) essentially equal to 1982 (33 per 100 m^3), the highest April on record. They were not notably abundant in March (20 per

100 m^3), typically their peak period, ranking tenth among 16 years. This suggests a shift in abundance peak rather than an overall increase in number.

6. Larval winter flounder were scarce in April (0.2 per 100 m^3) ranking below all previous April values except for 1984 (0) when both CWS pumps were out of service. Excluding 1984, the previous low value was 1.3 per 100 m^3 in 1990.

7. Seasnail larvae were absent in June for the first time in 1992. In previous years they ranged from 0.5 (1982) to 16 per 100 m^3 (1978). Their overall abundance index for 1992 was notably low.

The following additional comments concern the annual abundance data:

(1) The overall abundance value for American plaice in 1992 was the highest since 1980.

(2) Searobin eggs were particularly abundant in June 1987, hence the high abundance value for that year (see also Table 1, Volume II).

(3) Although monthly values viewed separately were not remarkably low, the overall abundance indices for larval sculpin and cunner were among the lowest on record in 1992.

No densities meeting the unusually high definition of the contingency sampling plan were encountered during 1992.

Ichthyoplankton populations sampled over a long time series typically display density variations of one order of magnitude, and two orders of magnitude are not unheard of (see Figures 4 and 5). Variations in spawning stock size and condition, food availability, predator densities, and physical variables such as water temperature and wind all contribute to the level of observed ichthyoplankton densities. In the few cases where 1992 monthly PNPS densities extended above or below all previous values, differences were relatively small. In cases such as mackerel which have been entrained in relatively high numbers for five years, the data probably reflect relatively strong stock biomass (NOAA 1991)*. Likewise persistently low densities of Atlantic cod eggs noted from 1988 to the present are consistent with a regional downturn in the size of the spawning population (NOAA 1991). A stock size which is at historically low levels may likewise explain the low numbers of larval flounder in April 1992.

C. Lobster Larvae Entrained

No larval lobsters (*Homarus americanus*) were found in the 1992 entrainment samples. Following is a summary of previous lobster larvae collections at PNPS, a total of 11 having been taken.

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*NOAA (National Oceanic and Atmospheric Administration). 1991. Status of the fishery resources off the northeastern United States for 1991. NOAA Technical Memorandum NMFS-F/NEC-86.

1991: none found.

1990: 2 larvae - 1 stage I, June 26; 1 stage IV August 23.

1983-1989: none found.

1982: 1 larva - stage I on June 14.

1981: 1 larva - stage IV on June 29.

1980: none found.

1979: 1 larva - stage I on July 14.

1978: none found.

1977: 3 larvae - 1 stage I, June 10; 2 stage I, June 17.

1976: 2 larvae - 1 stage I, July 22; 1 stage IV-V, August 5.

1975: 1 larva - stage I, date unknown.

1974: none found.

The lobster larvae collected in 1976 were obtained during a more intensive lobster larvae program which employed a 1-meter net, collecting relatively large sample volumes, in addition to the standard 60-cm plankton net (Marine Research 1977).** Both larvae taken in 1976 were collected in the meter net; none were found in the routine ichthyoplankton samples.

**Marine Research, Inc. 1977. Entrainment investigations and Cape Cod Bay Ichthyoplankton Studies, July-September 1976. III.C.1-1-71. In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 9. Boston Edison Company.

SECTION V

HIGHLIGHTS

1) Egg densities recorded in 1992 for Atlantic menhaden, searobin, tautog/cunner, windowpane, and American plaice were well within the range of densities observed over past years. Among larvae this was also true for Atlantic herring, fourbeard rockling, sculpin, tautog, radiated shanny, and mackerel.

2) Following four consecutive years in which they were uncommonly absent in February, cod eggs at least appeared during February 1992. They were however missing in March 1992; this occurred previously only in 1990.

3) Fourbeard rockling eggs were relatively uncommon in May and June ranking below corresponding values for May and June of every other year except one.

4) Atlantic mackerel eggs have been abundant in June samples over the past five years, probably a reflection of relatively strong stock biomass.

5) Larval sand lance were relatively common throughout their period of occurrence in 1992 but were particularly abundant in February and May.

6) Larval rock gunnel were numerous in April, equal to 1982, the highest April on record. Surprisingly they were not notably abundant in March, their usual peak month.

7) Larval winter flounder were scarce in April ranking below all previous values except 1984 when both CWS pumps were out of service.

8) Seasnail larvae were absent in June for the first time. In previous years they ranged from 0.5 to 16 larvae per 100 m^3. Their overall abundance index for 1992 was notably low.

9) Overall abundance indices for larval sculpin and cunner were among the lowest on record.

10) No lobster larvae were obtained in 1992. A total of 11 have been taken over the past 19 years.

11) No unusually high densities requiring contingency sampling were recorded in 1992.

Figure 4. Mean monthly densities per 100 m^3 of water in the PNPS discharge canal for the eight numerically dominant egg species and total eggs, 1992 (dashed line). Solid lines encompassing shaded area show high and low values over the 1975-1991 period.

Brevoortia tyrannus

Enchelyopus-_Urophycis_
Peprilus

Gadidae-Glyptocephalus

Prionotus spp.

Labridae-_Pleuronectes_

Scomber scombrus

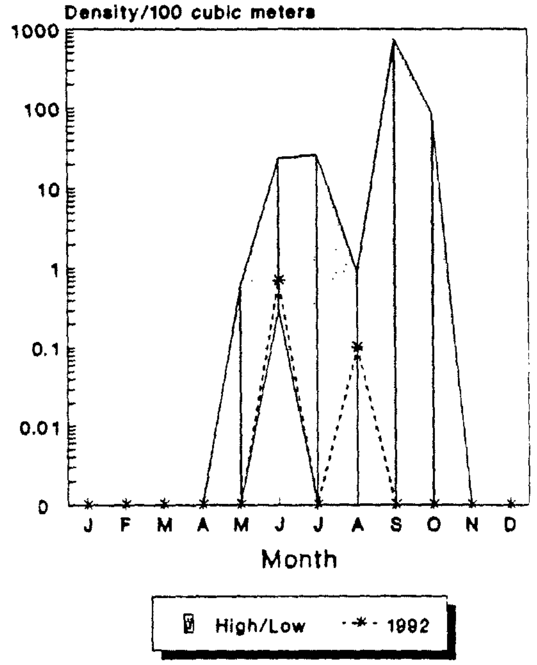
Paralichthys-_Scophthalmus_

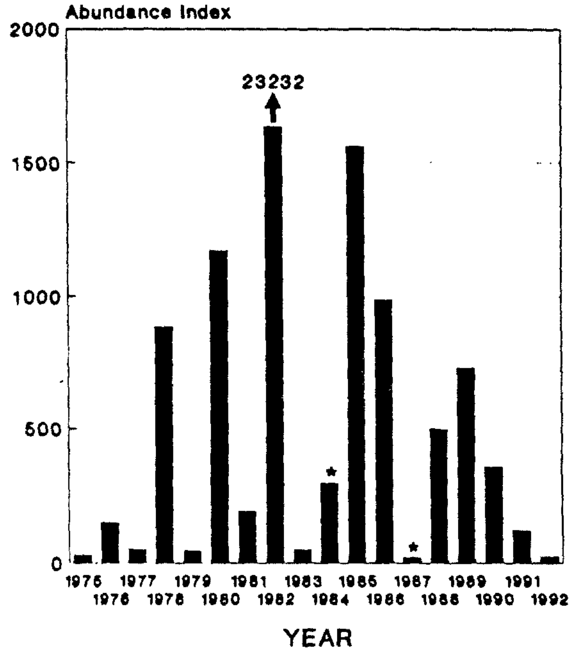
Hippoglossoides platessoides

Total eggs

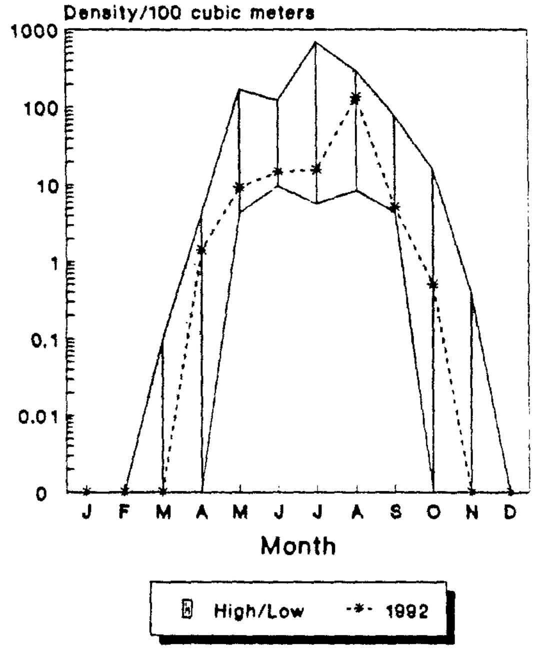
To the right are plotted integrated areas under the annual entrainment abundance curves for 1975-1992. An asterisk above 1984 and 1987 marks the two years when values may have been low due to low through-plant water volumes from April-August; see text for clarification.

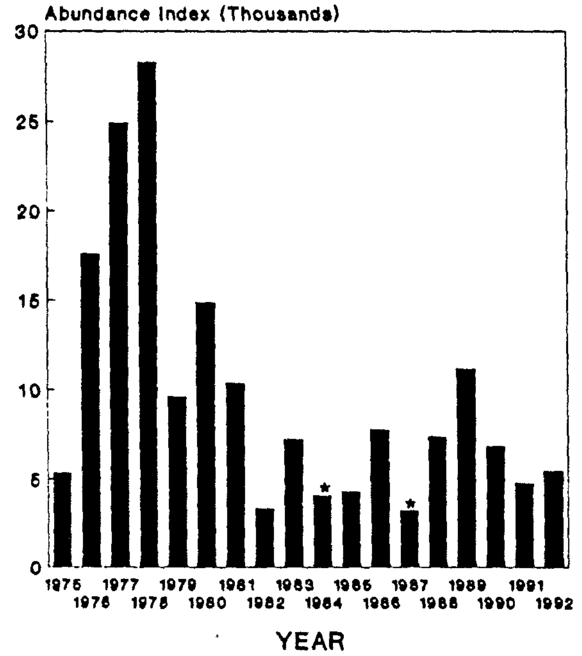
Brevoortia tyrannus
Eggs





Enchelyopus - Urophycis - Peprilus
Eggs

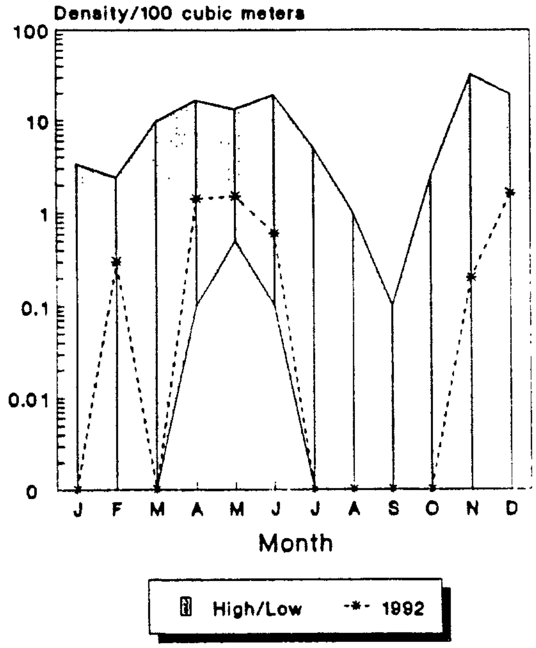


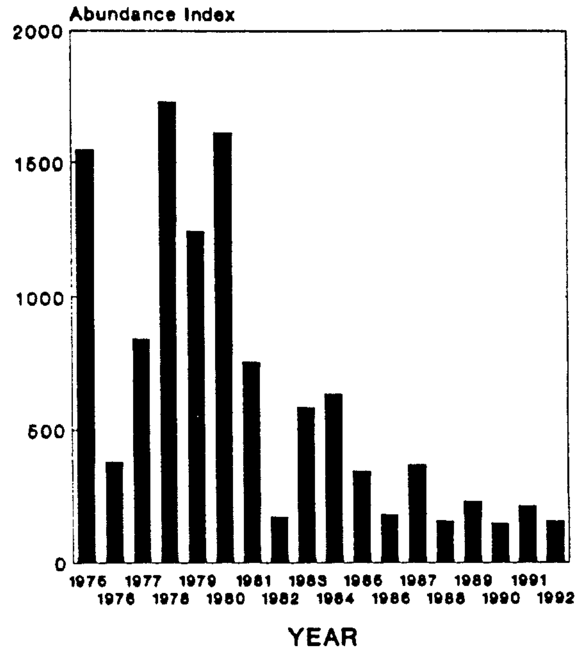


Includes:E.cimbrius, Urophycis spp., and P.triacanthus

Gadidae - *Glyptocephalus*

Eggs

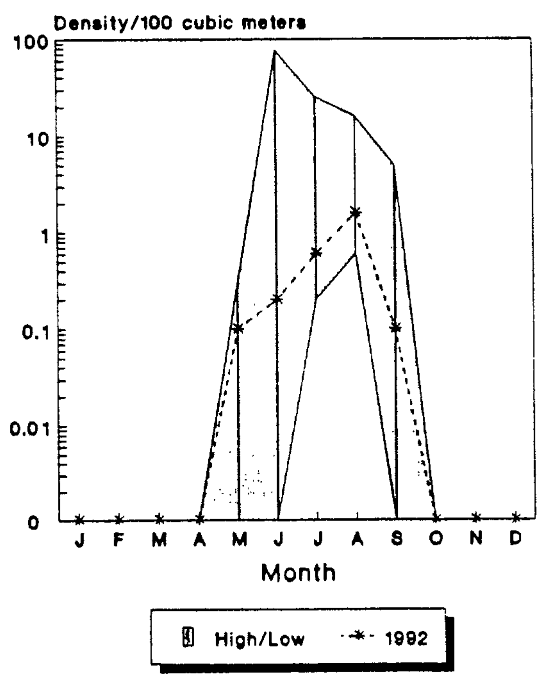


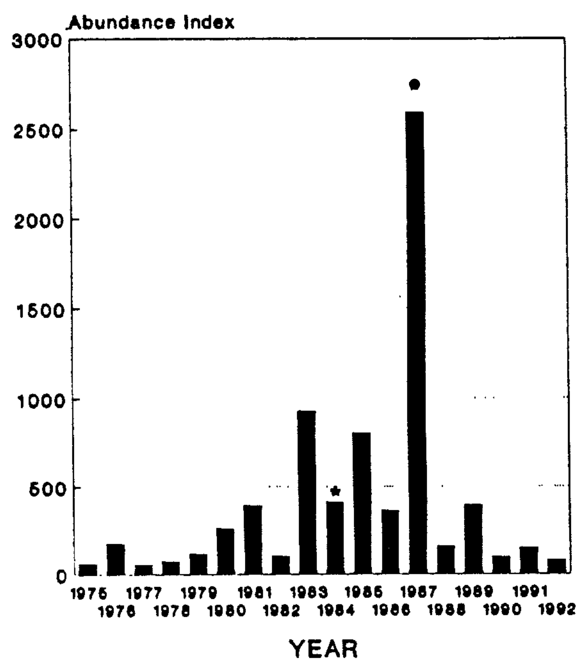


Includes:G.morhua, P.virens, and
G. cynoglossus

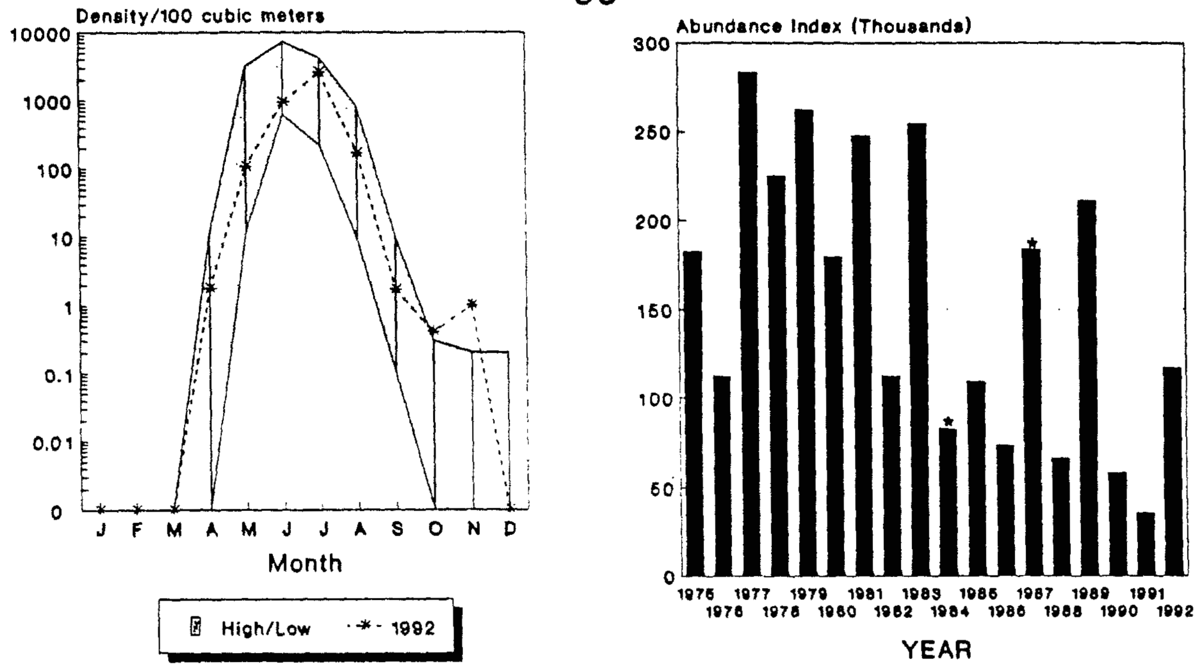
Prionotus spp.

Eggs



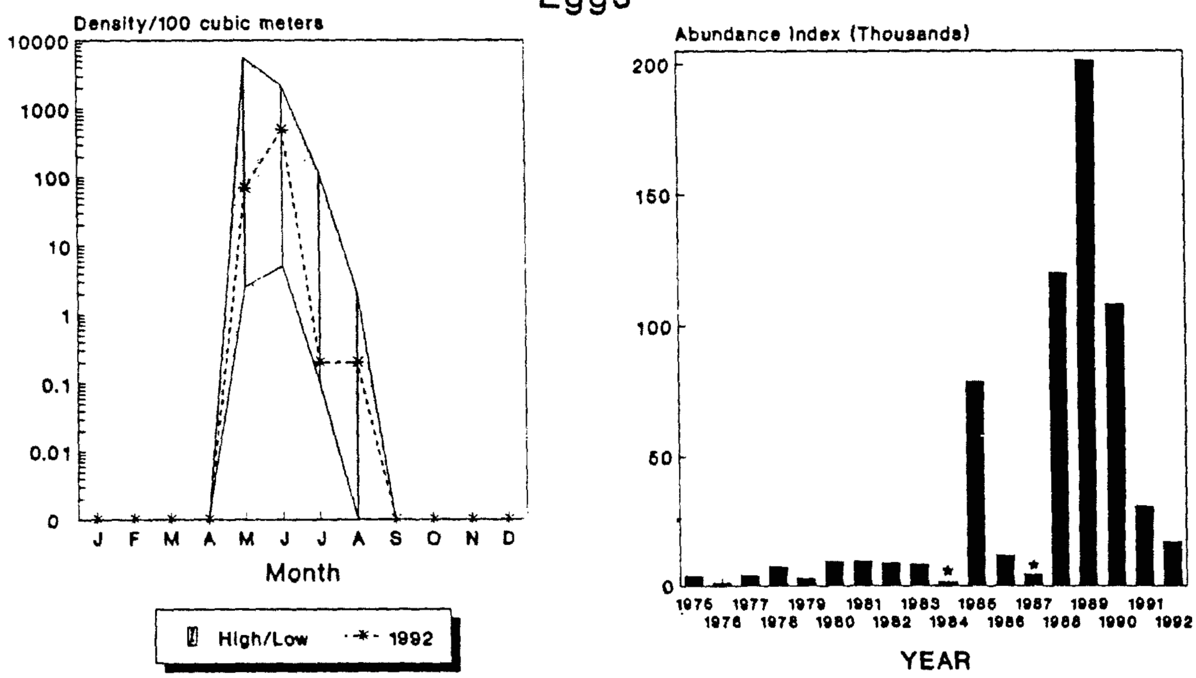


Labridae - *Pleuronectes*
Eggs

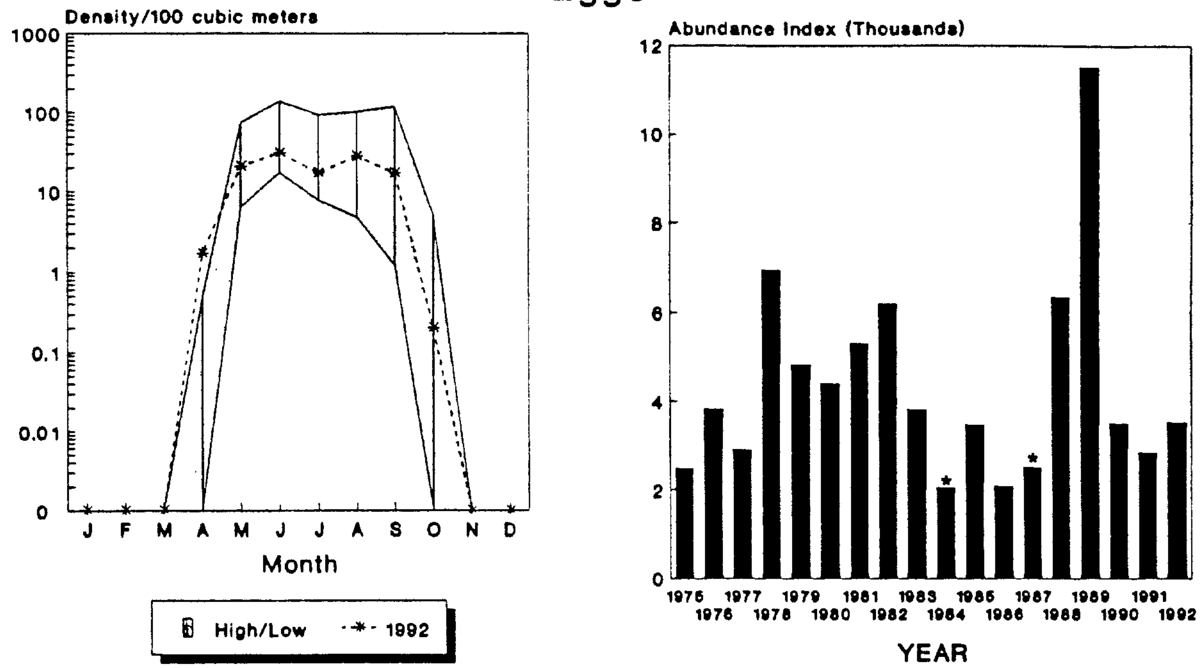


Includes Labridae and P. ferrugineus

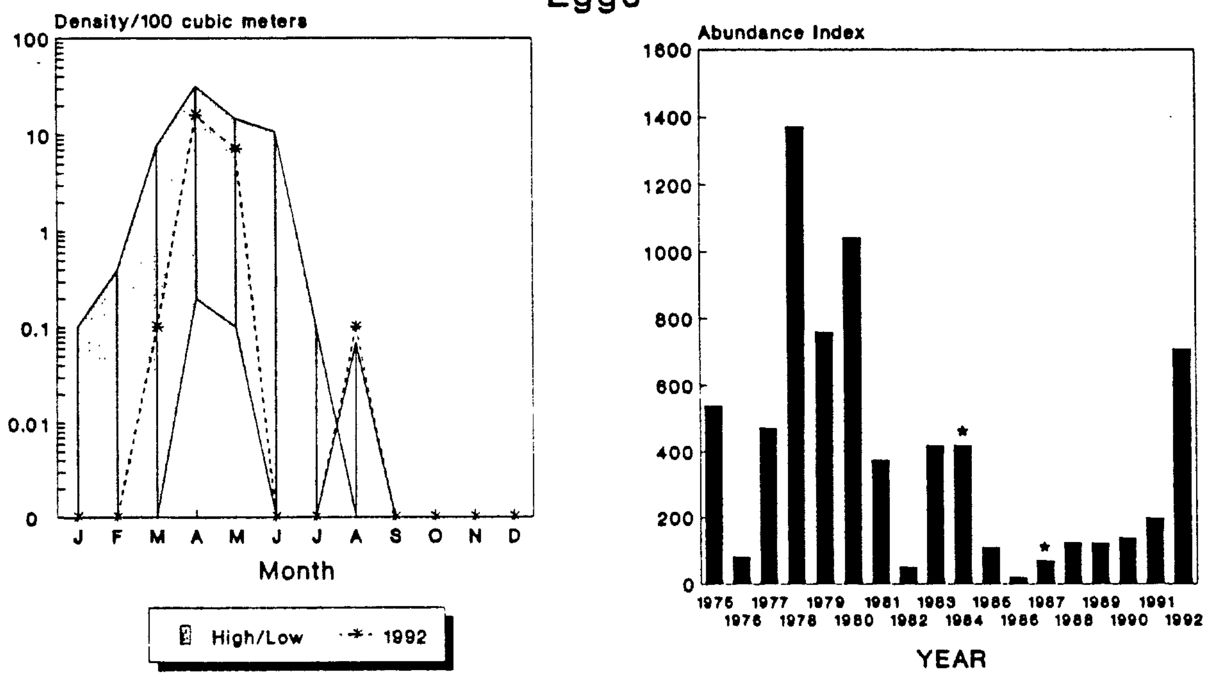
Scomber scombrus
Eggs



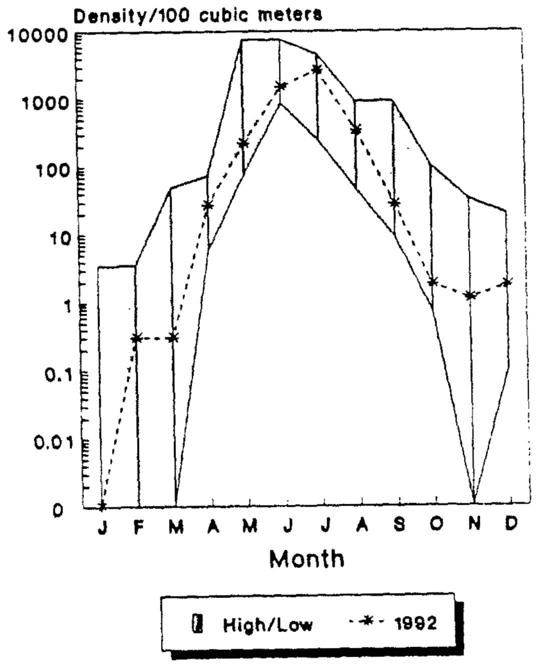
Paralichthys - Scophthalmus
Eggs



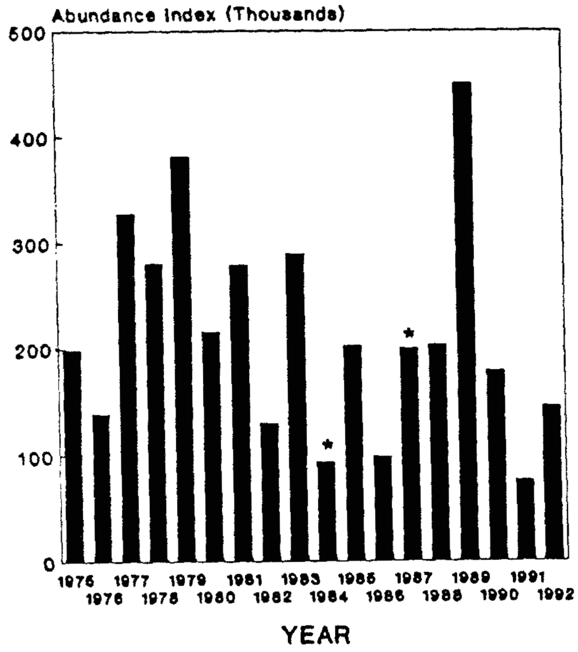
Hippoglossoides platessoides
Eggs



Total Eggs



Density/100 cubic meters
10000
1000
100
10
1
0.1
0.01
0
J F M A M J J A S O N D
Month
High/Low
1992



Abundance Index (Thousands)
500
400
300
200
100
0
1975 1977 1979 1981 1983 1985 1987 1989 1991
1976 1978 1980 1982 1984 1986 1988 1990 1992
YEAR

Figure 5. Mean monthly densities per 100 m^3 of water in the PNPS discharge canal for the eleven numerically dominant larval species and total larvae, 1992 (dashed line). Solid lines encompassing shaded area show high and low values over the 1975-1991 period.

Clupea harengus

Enchelyopus cimbrius

Myoxocephalus spp.

Liparis spp.

Tautoga onitis

Tautogolabrus adspersus

Ulvaria subbifurcata

Pholis gunnellus

Ammodytes sp.

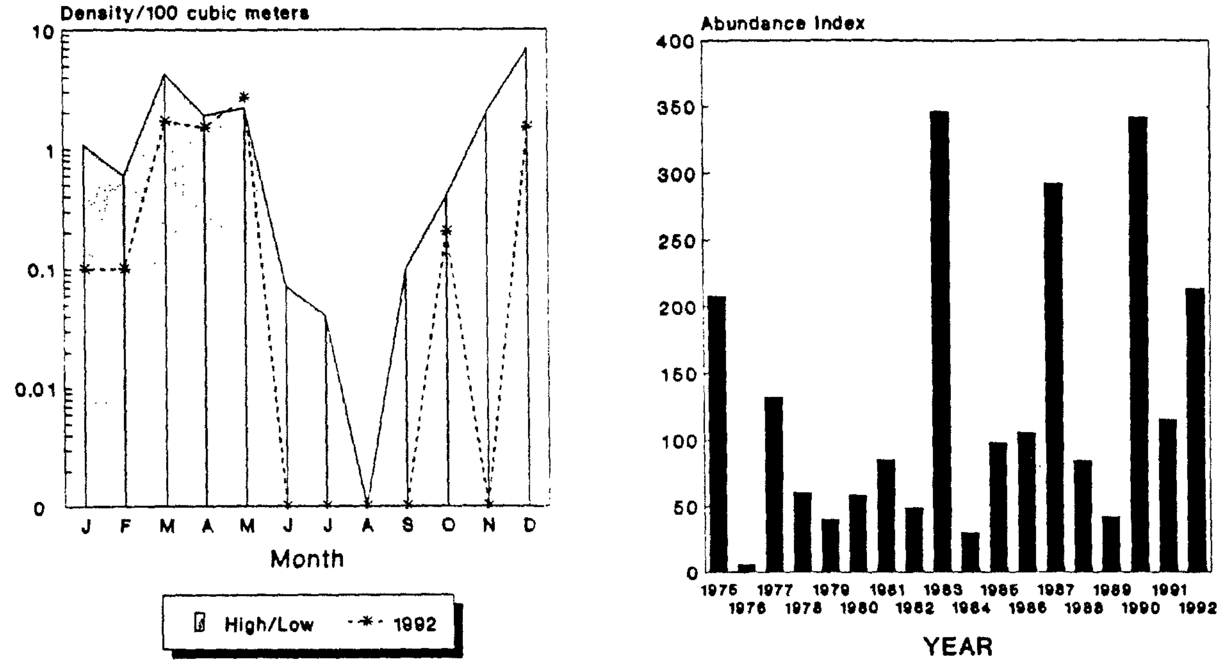
Scomber scombrus

Pleuronectes americanus

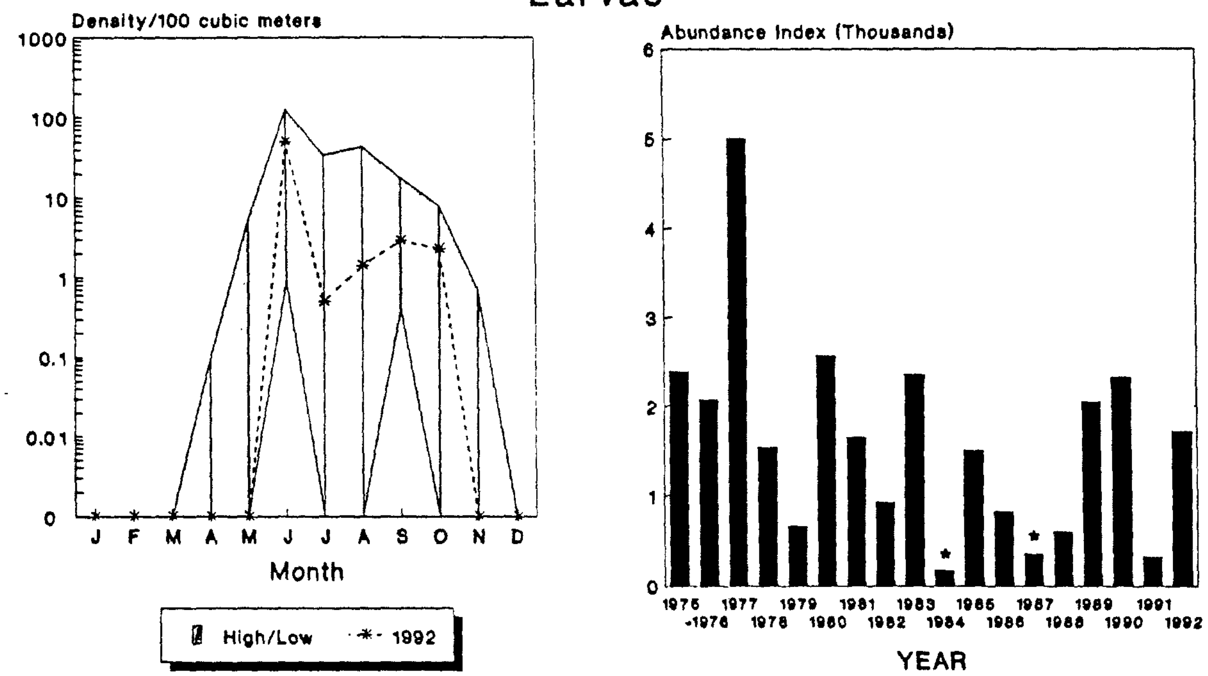
Total larvae

To the right are plotted integrated areas under the annual entrainment abundance curves for 1975-1992. An asterisk above 1984 and 1987 marks the two years when values may have been low due to low through-plant water volumes from April-August; see text for clarification.

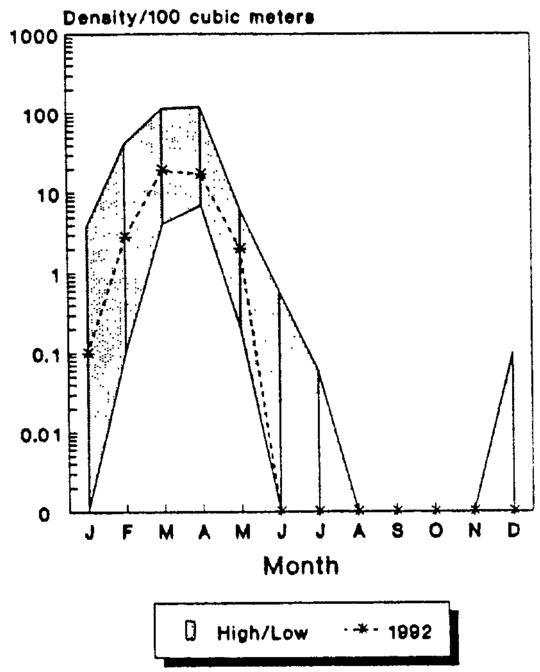
Clupea harengus
Larvae

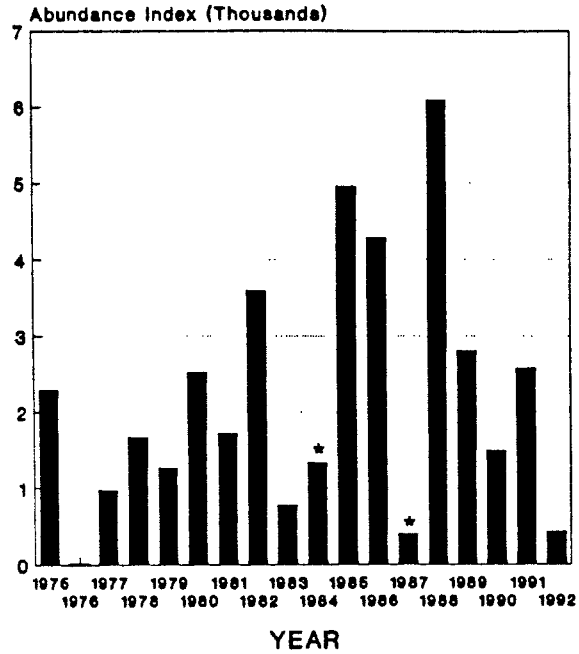


Enchelyopus cimbrius
Larvae

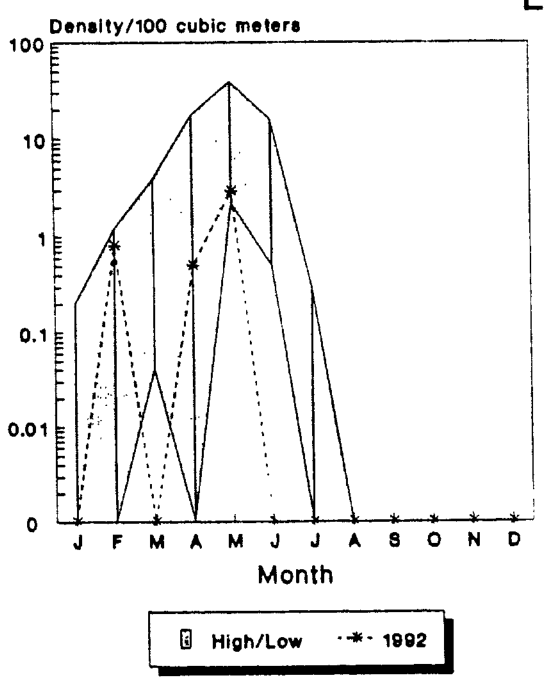


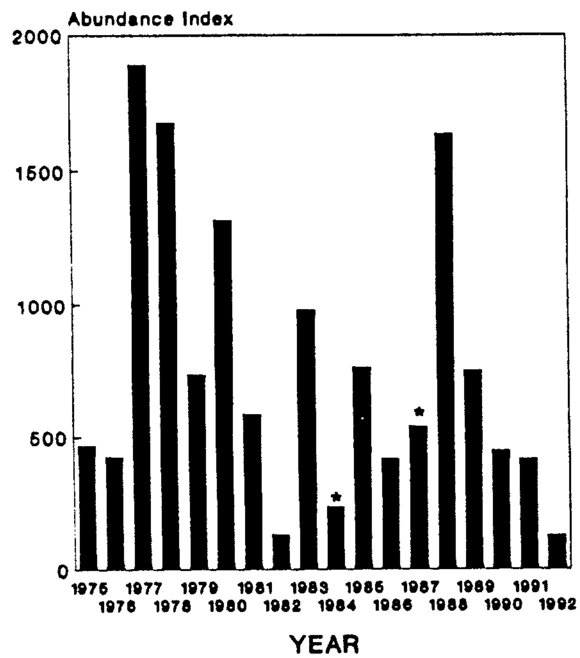
Myoxocephalus spp.
Larvae



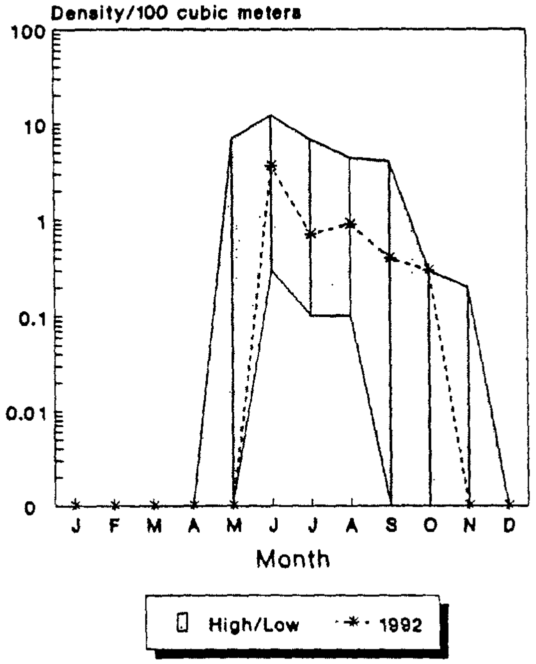


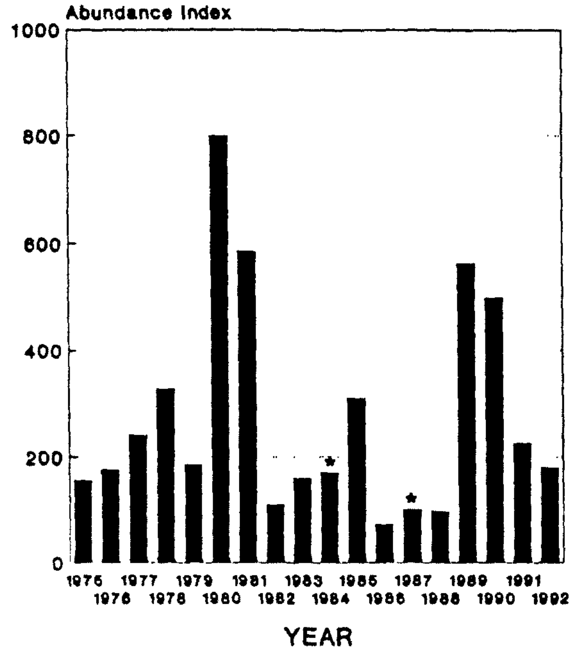
Liparis spp.
Larvae



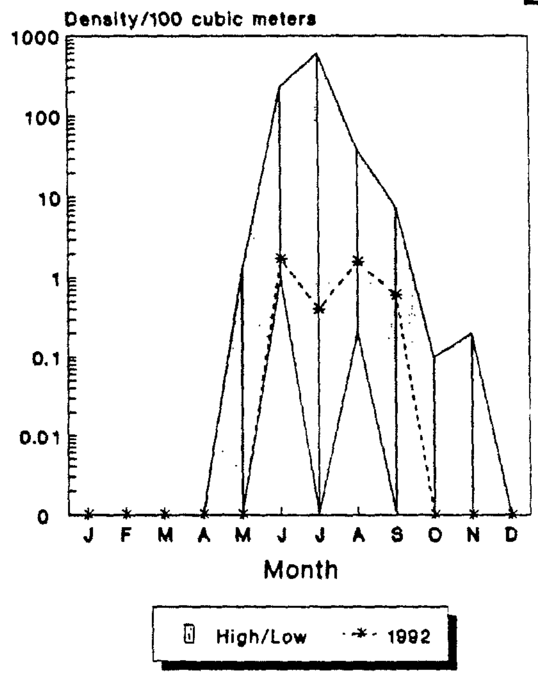


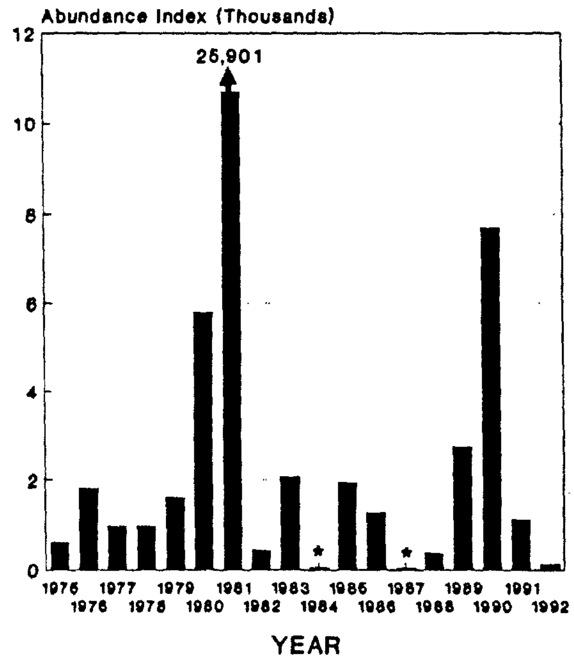
Tautoga onitis
Larvae



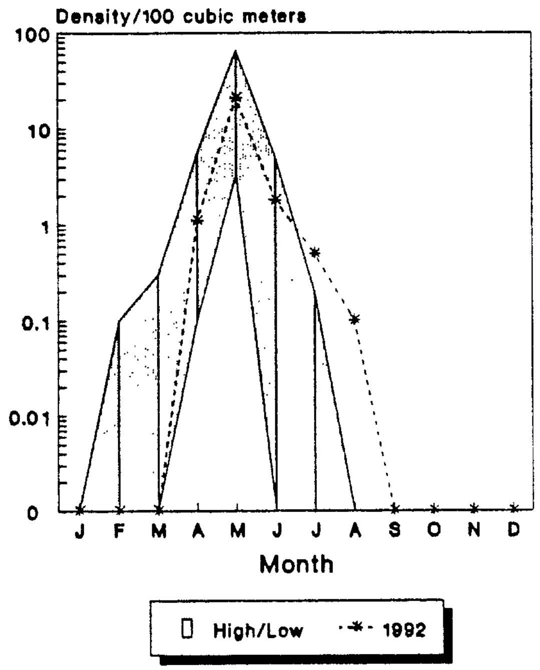


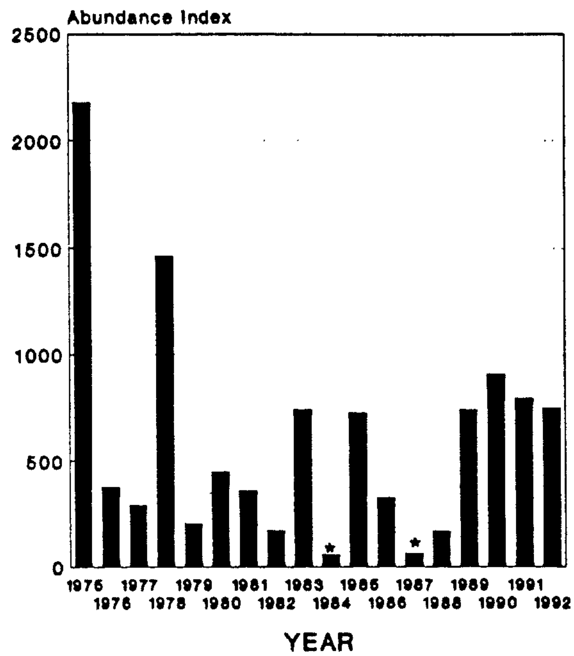
Tautogolabrus adspersus
Larvae



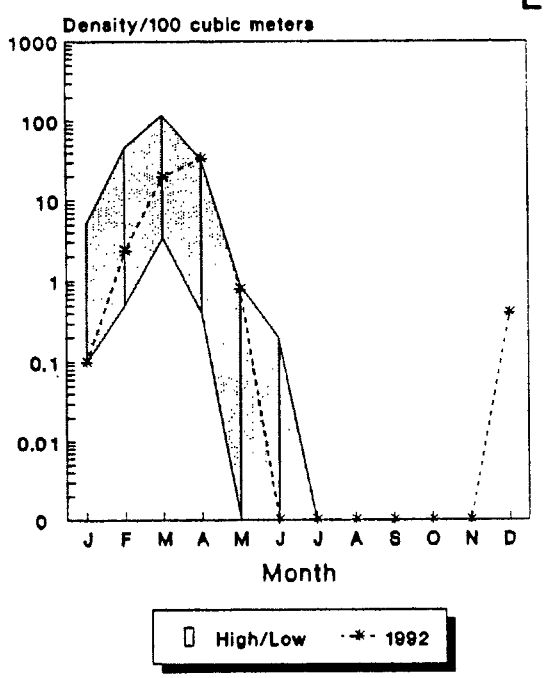


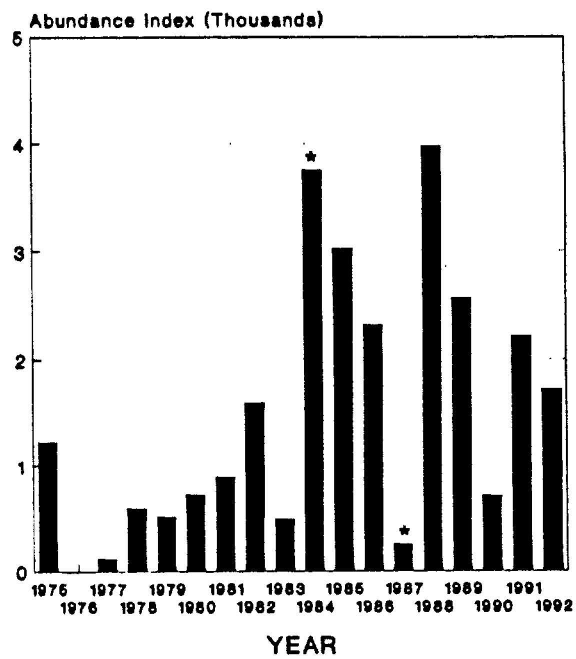
Ulvaria subbifurcata
Larvae



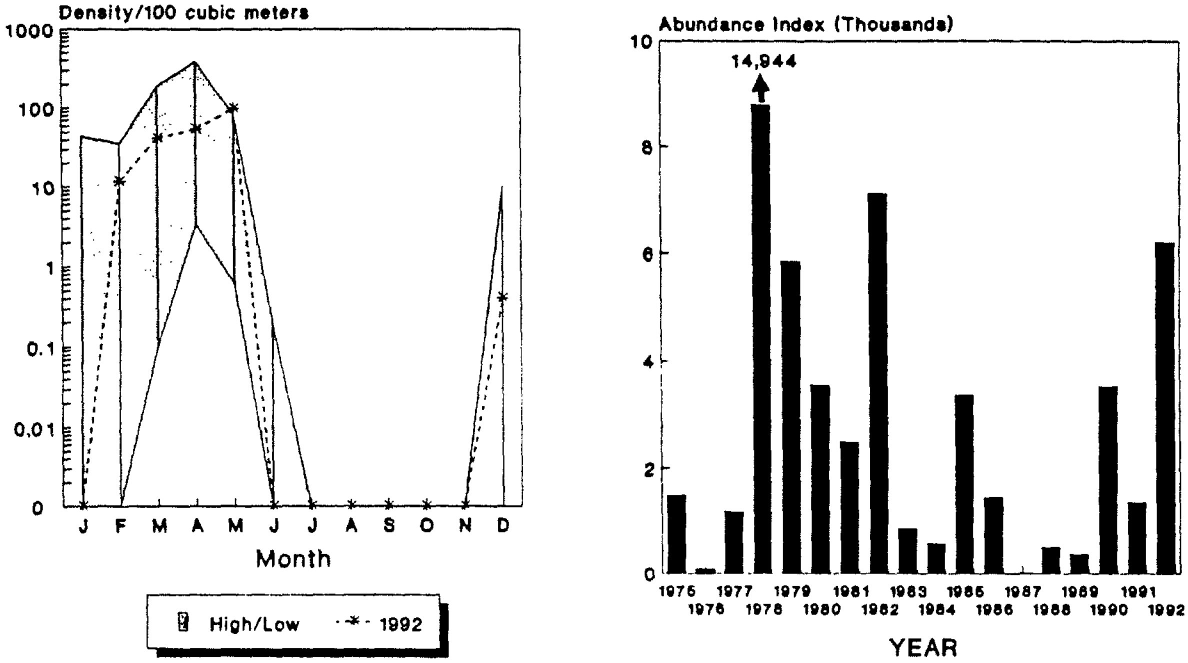


Pholis gunnellus
Larvae

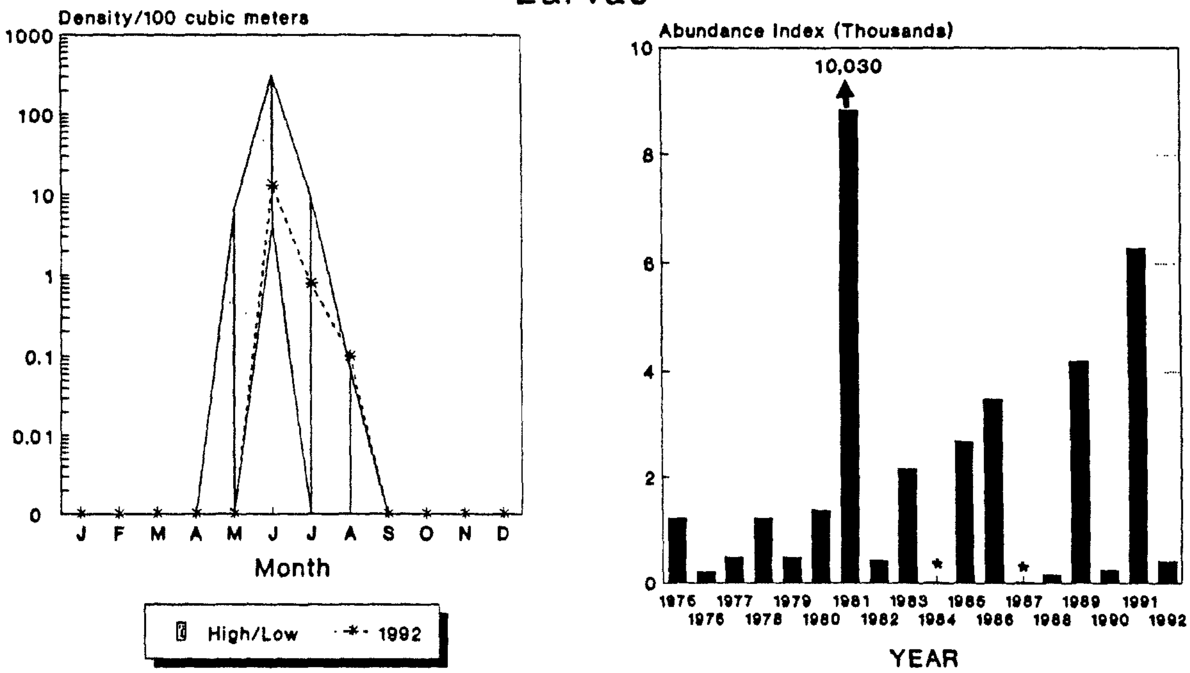




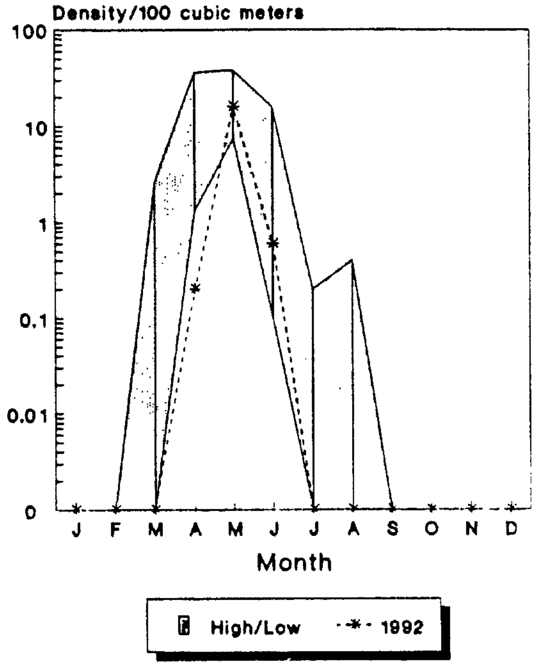
Ammodytes sp.
Larvae

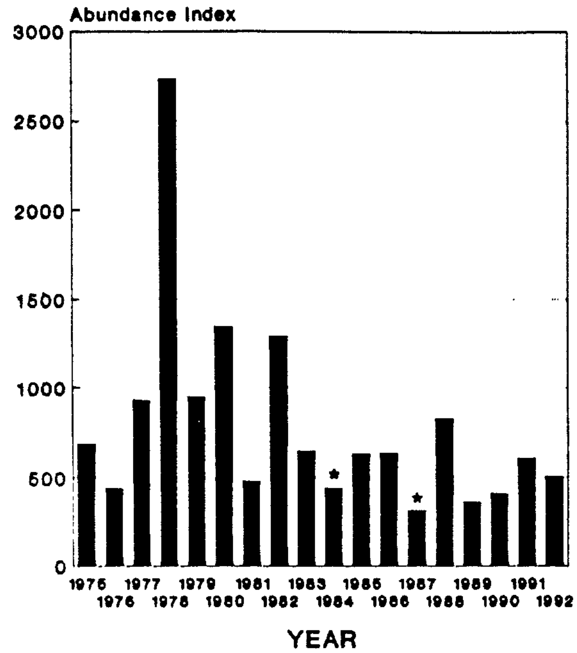


Scomber scombrus
Larvae

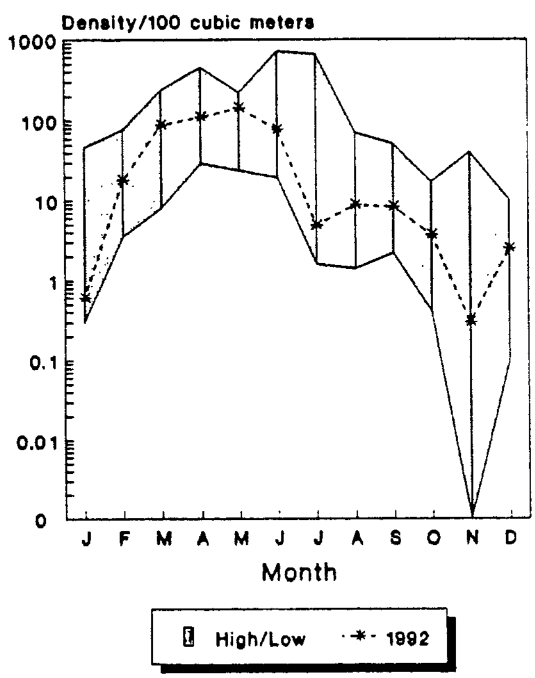


Pleuronectes americanus
Larvae





Total Larvae



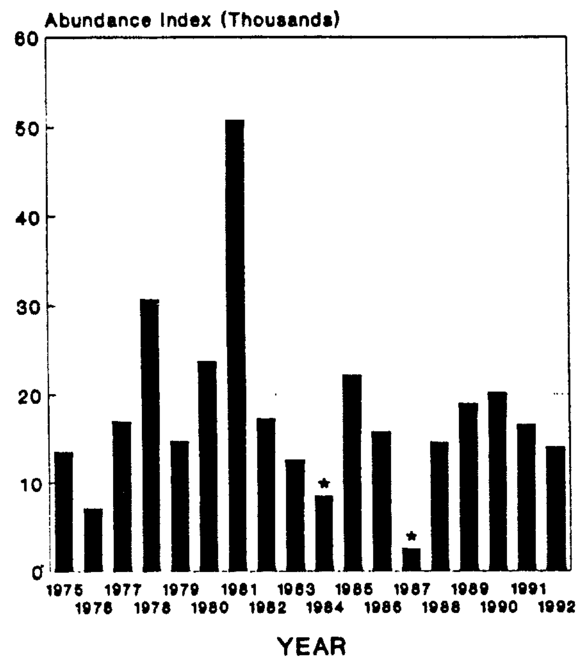


Table 1. Species of fish eggs (E) and larvae (L) obtained in ichthyoplankton collections from the Pilgrim Nuclear Power Station discharge canal, January-December, 1992. Lines indicate peak periods for the more abundant species.

Species		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Atlantic menhaden	*Brevoortia tyrannus*						E/L	L	E/L			L	
Atlantic herring	*Clupea harengus*	L	L	L	L	L					L		L
Bay anchovy	*Anchoa mitchilli*						E						
Anchovy	*Anchoa* spp.							L		L			
Rainbow smelt	*Osmerus mordax*					L							
Fourbeard rockling	*Enchelyopus cimbrius*				E	E	E/L	E/L	E/L	E/L	E/L		
Atlantic cod	*Gadus morhua*		E	E/L	E/L	E	E/L					E	E/L
Silver hake	*Merluccius bilinearis*						E/L		E/L	E/L	E		
Atlantic tomcod	*Microgadus tomcod*				L								
Pollock	*Pollachius virens*					L	L					E	
Hake	*Urophycis* spp.						E	E	E/L	E/L	L		
Goosefish	*Lophius americanus*					E			E	E/L			
Silversides	*Menidia* spp.							L		L			
Striped killifish	*Fundulus majalis*									E			
Northern pipefish	*Syngnathus fuscus*						L	L	L		L		
Searobins	*Prionotus* spp.					E	E	E	E	E			
Grubby	*Myoxocephalus aenaeus*		L	L	L	L							
Longhorn sculpin	*M. octodecemspinosus*	L	L	L	L	L							
Shorthorn sculpin	*M. scorpius*		L	L	L								
Lumpfish	*Cyclopterus lumpus*					L	E						
Seasnail	*Liparis atlanticus*				L	L	L						
Gulf snailfish	*L. coheni*	L	L										
Scup	*Stenotomus chrysops*						L	L					

Table 1 (continued).

Species		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Wrasses	Labridae					E	E	E	E	E	E		
Tautog	Tautoga onitis						L	L	L	L	L		
Cunner	Tautogolabrus adspersus						L	L	L	L			
Radiated shanny	Ulvaria subbifurcata				L	L	L	L	L				
Rock gunnel	Pholis gunnellus	L	L	L	L	L							L
Wrymouth	Cryptacanthodes maculatus			L	L								
Sand lance	Ammodytes sp.		L	L	L	L							L
Atlantic mackerel	Scomber scombrus					E	E/L	E/L	E/L				
Smallmouth flounder	Etropus microstomus							E	E	E			
Fourspot flounder	Paralichthys oblongus						L			L			
Windowpane	Scophthalmus aquosus				E	E	E/L	E/L	E/L	E/L	E/L		
Witch flounder	Glyptocephalus cynoglossus				E		E/L	E		E			
American plaice	Hippoglossoides platessoides			E	E/L	E/L	L		E				
Winter flounder	Pleuronectes americanus			E	E/L	E/L	L						
Yellowtail flounder	P. ferrugineus				E	E	L	E	E/L			E	

Table 2. Species of fish eggs (E) and larvae (L) collected in the PNPS discharge canal, 1975-1992. General periods of occurrence for eggs and larvae combined are shown along the right side; for the dominant species, periods of peak abundance are also shown in parentheses.

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Period of Occurrence
Anguilla rostrata	J*	J	J		J	J								J		J			Feb - Jun
Alosa spp.		L	L	J	L						L					J			May - Jul
Brevoortia tyrannus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Jun) - (Oct)Dec
Clupea harengus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan - Dec**
Anchoa spp.	L		L	L	L		L	L	L	L	L	L	L	L	L	L	L	L	Jun - Sep
A. mitchilli			E	E	E		E	E/L			E	E			E	E	E	E	Jun - Sep
Osmerus mordax	L	L	L	L	L		E/L	L	L		L	L	L	L	E/L			L	Apr - Jun
Brosme brosme	E/L	E/L	E/L		E/L	E/L	E	E	E										Apr - Jul
Enchelyopus cimbrius	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Jun) - (Sep)Dec
Gadus morhua	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Nov) - (Dec)Dec
Melanogrammus aeglefinus	L	E/L	E/L	E/L	L				L		E			E		E			Apr - Jul
Merluccius bilinearis	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	May(May) - (Jun)Nov
Microgadus tomcod			L	L		L	L	L	L	L	L	L	L	L	L	L		L	Jan - May
Pollachius virens	E/L	E/L	E	E/L	E/L	E/L	L			L	E/L	L	E/L	L	L	L	L	E/L	Jan-Jun,Nov,Dec
Urophycis spp.	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Aug) - (Sep)Nov
Ophidiidae-Zoarcidae	L																		Sep
Lophius americanus	E/L	E	E/L	E/L	E/L	L	E/L	E/L	E/L	E/L	E/L	E	E	E	E/L	E/L	E/L	E/L	May - Oct
Strongylura marina			L																Jul
Fundulus spp.		E	E																Jul
F. heteroclitus					E														Jun
F. majalis					J													E	Oct
Menidia spp.		L	L	L	L	E/L	E/L	E	E/L	L	L	L	L	L	L	L	L	L	May - Sep
M. menidia	E/L	E/L	E						L								E		May - Sep

*J = juvenile.

**Absent August and September; peaks = March-May and November-December.

Table 2 (continued).

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Period of Occurrence
Syngnathus fuscus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Apr - Oct
Sebastes norvegicus															L				Jun
Prionotus spp.	E/L	E		E	E	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E	E	E	E	May(Jun) - (Aug)Sep
Myoxocephalus spp.	L	L	L	L	L	L	L	L	E/L	L	E/L	L	L	L	E/L	L	E/L	L	Dec(Mar) - (Apr)Jul
M. aenaeus					L	L	L	L	L	L	L	L	L	L	L	L	E/L	L	Jan(Mar) - (Apr)Jul
M. octodecemspinosus						L	L	L	L	L	L	L	L	L	E/L	L	L	L	Jan(Mar) - (Apr)May
M. scorpius						L	L	L		L	L	L	L	L	L	L	L	L	Feb - Apr
Aspidophoroides monopterygius						L	L	L								L			Mar - Apr
Cyclopterus lumpus		L	L				L	L	E		L		L	L	L	E/L		E/L	Apr - Jul
Liparis spp.	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Apr) - (Jun)Jul
L. atlanticus							L	L	L	L	L	L	L	L	L	L	L	L	Mar(Apr) - (Jun)Jul
L. coheni							L	L	L	L	L	L	L	L	L	L	L	L	Jan(Feb) - (Mar)Apr
Centropristis striata	L					L			L	L	L	L	L	L	L	L			Jul - Oct
Cynoscion regalis						L					L	L							May - Sep
Stenotomus chrysops	L		L											L	E	L	L	L	Jun - Jul
Menticirrhus saxatilis	L				L														Jul - Aug
Labridae	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	Mar(May) - (Aug)Sep
Tautoga onitis	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	May(Jun) - (Aug)Oct
Tautogolabrus adspersus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	May(Jun) - (Aug)Oct
Lumpenus lumpretaeformis	L						L			L	L	L		L	L	L			Jan - Jun
Ulvaria subbifurcata	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Feb(Apr) - (Jun)Oct
Pholis gunnellus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Feb) - (Apr)Jun
Cryptacanthodes maculatus				L	L		L	L	L	L	L	L			L	L	L	L	Feb - Apr
Ammodytes sp.	L	L	L	L	E/L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Mar) - (May)Jun
Gobiosoma ginsburgi	L		L					L						L					Jul - Aug
Scomber scombrus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(May) - (Jul)Sep
Peprilus triacanthus	E/L	E/L	E/L	E	E	E/L	E/L	L	E/L	E/L	L		E	E/L	E/L	L	E/L		May - Oct

Table 2 (continued).

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Period of Occurrence
Etropus microstomus	L								L		E	E/L	E		E		E	E	Jul - Oct
Paralichthys dentatus	E/L								E/L		L		E/L	E		L			Sep - Nov
*P. oblongus**		E/L	E/L		E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	L	May - Oct
*Scophthalmus aquosus**	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(May) - (Sep)Oct
Glyptocephalus cynoglossus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Mar(May) - (Jun)Nov
Hippoglossoides platessoides	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Mar) - (Jun)Nov
Pleuronectes americanus	E/L	E/L	L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Apr) - (Jun)Aug
P. ferrugineus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Feb(Apr) - (May)Nov
P. putnami							L	E/L											Mar - Jun
Trinectes maculatus			E	E			E	E				E		E	E/L	E/L	E		May - Sep
Sphoeroides maculatus			L								L								Jul - Aug
Number of Species**	41	36	43	35	37	35	40	38	37	34	42	37	36	41	40	42	34	36	

*Although these eggs were not identified specifically, they were assumed to have occurred as shown based on the occurrence of larvae.
**For comparative purposes three species of *Myoxocephalus* were assumed for 1975-1978 and two species of *Liparis* for 1975-1980.

APPENDIX A*

Densities of fish eggs and larvae per 100 m^3 of water recorded in the PNPS discharge canal by species, date, and replicate, January-December 1992.

*This Appendix is available upon request.

APPENDIX B*

Mean monthly densities and range per 100 m^3 of water for the dominant species of fish eggs and larvae entrained at PNPS, January-December, 1975-1992.

*This Appendix is available upon request.

ICHTHYOPLANKTON ENTRAINMENT MONITORING

AT PILGRIM NUCLEAR POWER STATION

JANUARY-DECEMBER 1992

Volume 2 of 2

(Impact Perspective)

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

April 15, 1993

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SECTION I

EXECUTIVE SUMMARY

Entrainment sampling at PNPS was scheduled twice per month during January, February, October, November, December and weekly from March through September. With the exception of one April date and in November, all collections were made with both circulating water system pumps in service. One CWS pump was in operation on April 7 and in November.

Ichthyoplankton densities meeting the "unusually abundant" criterion defined under the contingency sampling program were not recorded in 1992, the last occasion being in February and March 1988. Based on full load flow capacity, total numbers of eggs which may have been entrained by PNPS in 1992 were estimated to range from 426,059 for Atlantic menhaden to 1,753,758,934 for the labrid-yellowtail group. Corresponding values among the eleven dominant larval species ranged from 2,222,841 for seasnails to 108,323,789 for sand lance.

Annual entrainment losses of cunner eggs and larvae, mackerel eggs and larvae, and winter flounder larvae were examined in more detail using the equivalent adult approach. For 1987-1992 an annual average of 54,763 adult cunner, 6496 age I mackerel, and 628 age III flounder were estimated to have been lost due to the effects of entrainment.

Recent declines in abundance of cunner, windowpane, yellowtail flounder, and winter flounder in collections around PNPS appear to be widespread and therefore unlikely to be directly related to entrainment of eggs and larvae.

An analysis of egg and larval entrainment between years with differing pump regimes indicates that larval entrainment and perhaps, to a lesser extent, egg entrainment are directly related to water withdrawal rates.

No lobster larvae were collected in PNPS entrainment samples in 1992.

SECTION II

INTRODUCTION

This report addresses results of PNPS ichthyoplankton entrainment sampling in relation to potential impact assessment. Discussions are based on results presented in "Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January-December 1992", Volume 1 - Results. Work was conducted by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 69010 in compliance with environmental monitoring and reporting requirements of the PNPS NPDES Permit (U.S. Environmental Protection Agency and Massachusetts Division of Water Pollution Control). In a continuing effort to condense the volume of material presented in this and related reports, details of interest to some readers may have been omitted. Any questions or requests for additional information may be directed to Marine Research, Inc., Falmouth, Massachusetts, through BECO.

Plate 1 shows the ichthyoplankton sampling net being deployed on station in the PNPS discharge canal.

Plate 1. Plankton net streaming in the discharge canal at Pilgrim Station for the collection of fish eggs and larvae (lobster larvae are also recorded). A single, six-minute collection can contain several thousand eggs and larvae representing 20 or more species.

SECTION III

IMPACT PERSPECTIVE

A. Contingency Sampling Plan

Ichthyoplankton densities in the PNPS discharge canal meeting the "unusually abundant" criterion, defined as exceeding by 50% the highest mean density over three replicates recorded during the same month from 1975 through 1991, did not occur in 1992. This marked the fourth straight year of no unusual occurrences. Two occasions were noted in 1988, no occurrences in 1987 or 1986, four in 1985, six in 1984, one in 1983, eight in 1982, seven in 1981, and twelve in 1980 (Table 1). No specific events were recorded prior to 1980 primarily because "unusually abundant" was not precisely defined early in the contingency plan.

In past years it was standard practice for BECO, in consultation with regulatory personnel, to authorize the collection of an additional set of triplicate entrainment samples following the recording of an unusually large density at PNPS. In most cases the additional sets were taken within two days of the original. In all but three cases when this occurred mean densities dropped back to levels within the range established over previous years, indicating that the "unusual" density probably reflected the occurrence of a high-density ichthyoplankton patch in the Rocky Point area rather than a more widespread phenomenon. In the three cases where high densities persisted (larval Atlantic menhaden, *Brevoortia tyrannus*, June 1981; larval rock gunnel, *Pholis gunnellus*, April 1982; larval

Table 1. Ichthyoplankton densities per 100 m³ of water which reached the "unusually abundant"* level in PNPS entrainment samples, 1980-1992.

Species	Month	"Unusually abundant" density (year)	Previous high density (year)
EGGS			
Brevoortia tyrannus	June	74.2 (1980)	6.2 (1978)
	September	1961.9 (1982)	1.4 (1979)
		1065.8 (1982)	" "
	October	37.8 (1980)	0.2 (1978)
Enchelyopus-Urophycis Peprilus	September	71.3 (1980)	30.1 (1979)
Urophycis spp.	September	152.8 (1980)	22.3 (1978)
Labrid-Limanda & labrid	July	12917.0 (1981)	8116.8 (1975)
Scomber scombrus	May	15261.3 (1985)	572.0 (1980)
		1457.6 (1985)	" "
LARVAE			
Brevoortia tyrannus	June	7.1 (1981)**	4.2 (1980)
		495.9 (1981)**	" "
		34.7 (1981)**	" "
	October	11.7 (1980)	1.8 (1976)
	November	24.3 (1980)	3.2 (1978)
Enchelyopus cimbrius	August	204.6 (1983)	36.0 (1980)
Urophycis spp.	September	105.6 (1984)	22.3 (1981)
Tautoga onitis	August	21.6 (1984)	4.1 (1974)
	September	9.2 (1980)	4.8 (1975)
Tautogolabrus adspersus	June	624.5 (1981)	378.8 (1977)
	July	296.5 (1980)	138.5 (1974)
		2162.5 (1981)	296.5 (1980)
	September	20.3 (1980)	1.5 (1975)
Pholis gunnellus	February	19.6 (1984)	7.4 (1975)
		13.8 (1984)	" "
		47.5 (1985)**	19.6 (1984)
	March	70.2 (1980)	36.9 (1975)
		210.5 (1984)	70.2 (1980)
		415.2 (1984)	" "
	April	74.0 (1982)**	12.1 (1977)
		74.7 (1982)**	" "
		34.0 (1982)**	" "
		22.4 (1982)**	" "
		23.5 (1982)**	" "

Table 1 (continued).

Species	Month	"Unusually abundant" density (year)	Previous high density (year)
LARVAE (continued)			
Ammodytes sp.	January	31.1 (1980)	13.5 (1975)
		104.4 (1985)	31.1 (1980)
Scomber scombrus	June	2700.0 (1981)	128.0 (1975)
Myoxocephalus spp.	February	79.2 (1988)	37.4 (1985)
	March	153.6 (1980)	97.0 (1975)
		308.3 (1988)	188.7 (1986)
	April	303.6 (1982)	53.1 (1981)

*"Unusually abundant" was defined as 50% greater than the previous high density observed during the same month 1975-1991.

**Unusually high densities persisted for up to two weeks.

rock gunnel, February 1985, additional entrainment sampling at about two-day intervals indicated that high densities continued for up to two weeks. Since no changes in PNPS operation occurred, it appeared in those situations that productivity was generally high relative to previous years.

As the declining number of "unusual" densities over time suggests, each "unusual" density increases the level necessary for future high-density events to be identified within a given species. In practice each unusual occurrence makes it more unlikely that any subsequent contingency events will be identified.

B. Ichthyoplankton Entrainment - General

Entrainment of ichthyoplankton at PNPS represents a direct, negative environmental impact since fish eggs and larvae pass through the plant in large numbers each day and are subjected to elevated temperatures, mechanical forces, and periodic chlorination. When PNPS is not on line, increased temperature is not a factor but ichthyoplankton may still be subjected to mechanical forces and periodic chlorination when circulating seawater or salt service water pumps operate. Although survival has been demonstrated for some species of fish eggs at PNPS such as the labrids (45%; Marine Research 1978, 1982) and among larvae at other power plants (0-100% initial survival depending on species and size; Ecological Analysts 1981), mortality is conservatively assumed to be 100% for PNPS impact assessment.

To place fish egg and larval densities entrained at PNPS, expressed as numbers per 100 m^3 of water, in some perspective in relation to amounts of water utilized by PNPS, they were multiplied by maximum plant flow rates over each respective period of occurrence. This was completed for each of the numerically dominant species as well as total eggs and total larvae. Mean monthly densities were multiplied by 17,461.44, the full load flow capacity of PNPS in 100 m^3 units per 24-hour day, then by the number of days in each respective month they occurred. Values for each month in which a species or species group occurred were then summed to arrive at a seasonal entrainment value in each case (Figures 1 and 2). Among the eight numerically dominant groups, numbers of eggs entrained ranged from 426,059 for Atlantic menhaden to 1,753,758,934 for the labrid-yellowtail group (tautog, *Tautoga onitis*, cunner, *Tautogolabrus adspersus*, yellowtail flounder, *Pleuronectes ferrugineus*). Corresponding values among the eleven dominant larval species varied from a low of 2,222,841 for sea snails (*Liparis* spp.) to a high of 108,323,789 for sand lance (*Ammodytes* sp.). For all eggs and all larvae combined, values amounted to 2,529,771,345 and 246,066,613, respectively. These numbers indicate the vast quantities of eggs and larvae which can be entrained by the circulating seawater system at PNPS during a year's time and are assumed to be lost to the local fish population.

Number of Eggs Entrained - 1992

SPECIES AND PERIOD OF OCCURRENCE

Brevoortia tyrannus (June-November)

Enchelyopus-*Urophycis*-*Peprilus* (April-October)

Gadidae-*Glyptocephalus* (January-November)

Prionotus spp. (June-September)

Labridae-*Pleuronectes* (May-October)

Scomber scombrus (May-September)

Paralichthys-*Scophthalmus* (May-October)

Hippoglossoides platessoides (April-June)

Total Eggs

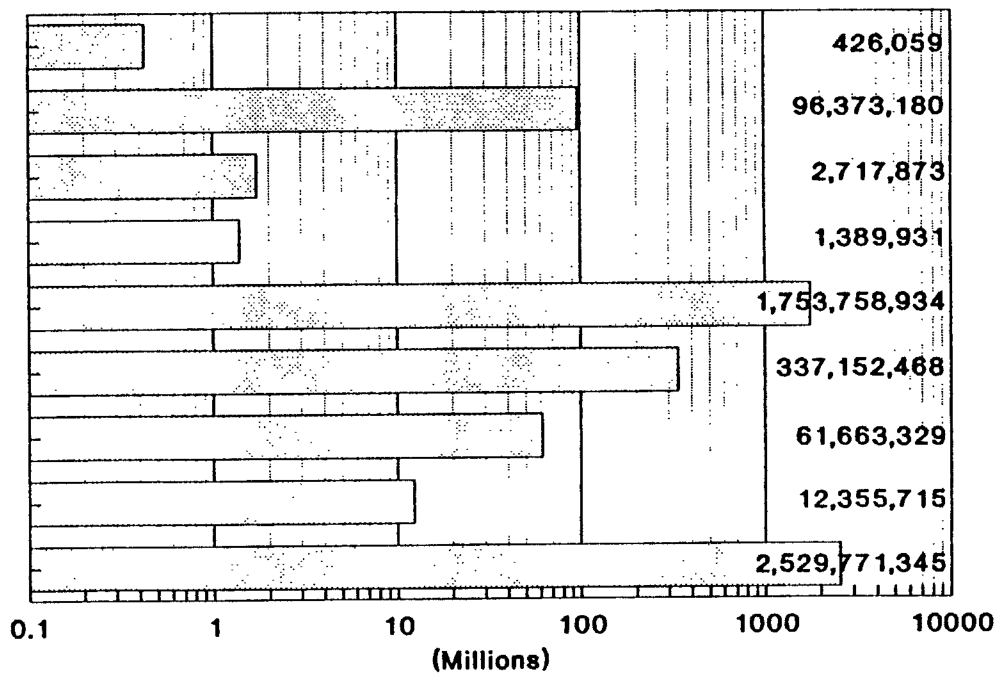

Figure 1. Numbers of eggs estimated to have been entrained by PNPS in 1992 had it operated at full pump flow by species or species group (dominants only) including all egg species combined. The period of occurrence observed in 1992 is also indicated.

Number of Larvae Entrained - 1992

SPECIES AND PERIOD OF OCCURRENCE

<u>Clupea</u> <u>harengus</u> (April-May, November-January)
<u>Enchelyopus</u> <u>cimbrius</u> (April-November)
<u>Myoxocephalus</u> spp. (February-June)
<u>Liparis</u> spp. (March-June)
<u>Tautoga</u> <u>onitis</u> (June-September)
<u>Tautogolabrus</u> <u>adspersus</u> (June-September)
<u>Ulvaria</u> <u>subbifurcata</u> (April-July)
<u>Pholis</u> <u>gunnellus</u> (January-May)
<u>Ammodytes</u> sp. (January-June)
<u>Scomber</u> <u>scombrus</u> (May-August)
<u>Pleuronectes</u> <u>americanus</u> (April-June)
Total Larvae

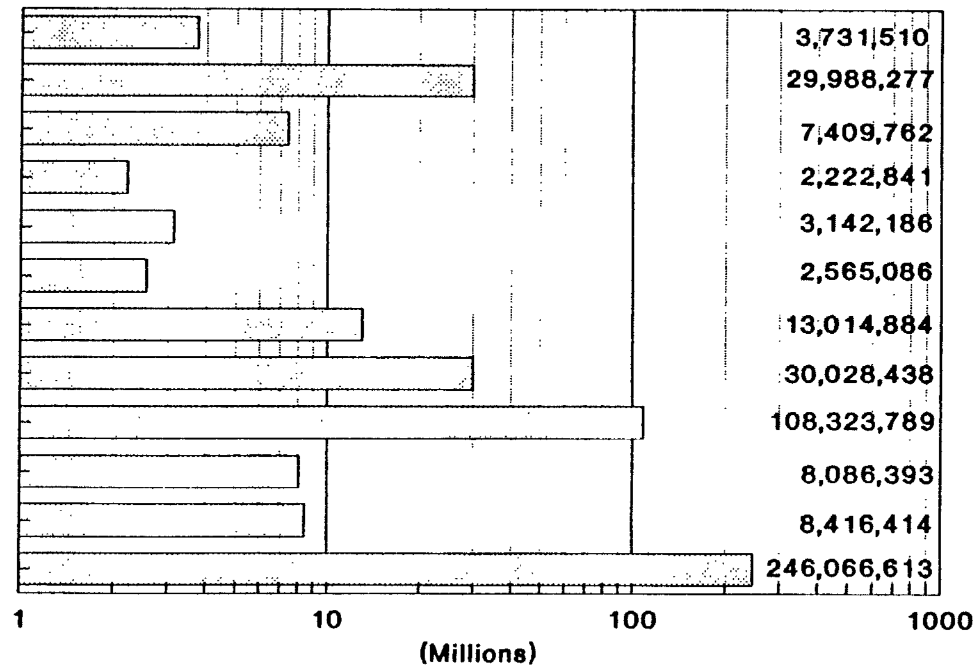

Figure 2. Numbers of larvae estimated to have been entrained by PNPS in 1992 had it operated at full pump flow for each dominant species including all larvae combined. The period of occurrence observed in 1992 is also indicated.

C. <u>Ichthyoplankton Entrainment - Specific</u>

Estimated numbers of eggs and larvae entrained annually were examined in greater detail for three species using the equivalent adult approach (see Horst 1976, Goodyear 1978, for example). Six years, 1987-1992, were arbitrarily selected for review. The adult equivalent procedure involves applying various survival rates to numbers of eggs and larvae lost to entrainment to obtain a number of adult fish which could have been added to the population had entrainment not occurred. Many assumptions are associated with the method. The fish population is assumed to be in equilibrium, therefore in her lifetime each female will replace herself plus one male. It is also assumed that no eggs or larvae survive entrainment and that no density-dependent compensation occurs among surviving individuals. The later two assumptions lend conservatism to the approach. As pointed out earlier, numbers of eggs and larvae entrained were determined using the full load flow capacity of the plant. This value was used even if the station was out of service and less than full capacity was being circulated. In those cases the adult equivalents are conservatively high.

The three species selected were winter flounder (<u>Pleuronectes americanus</u>), cunner (<u>Tautogolabrus adspersus</u>), and Atlantic mackerel (<u>Scomber scombrus</u>). Flounder were chosen because of their commercial and recreational value as well as their importance in PNPS ecology studies. Cunner were selected because they are abundant in the area and PNPS finfish studies have been focusing on that species. Mackerel were included because they are abundant among the ichthyoplankton entrained, both eggs and larvae being entrained, and they are commercially valuable. Each is discussed separately.

Winter flounder. The annual larval entrainment estimates were converted to equivalent numbers of age III adults, the age at which flounder become sexually mature, following the procedures discussed in NEP (1978) and MRI and NEP (1981). Although small numbers are entrained each year, flounder eggs were ignored because they are demersal and adhesive and not generally impacted by entrainment. Equivalent age III fish ranged from 422 to 1102, averaging 628 annually (1987 excluded because no April sampling occurred; Table 2). Over this same period an annual average of 1,748,129 pounds of flounder were landed from NOAA statistical area 514 which covers Cape Cod Bay and Massachusetts Bay. Based on a weight of 0.5 pound per fish, the loss of 628 fish weighing 314 pounds represents 0.02% of those landings.

Cunner. Goodyear's (1978) basic procedures were used to estimate equivalent adult values. This method does not specify age. Assuming all labrid eggs were cunner eggs in PNPS entrainment samples (Scherer 1984), cunner larvae:egg ratios were determined from PNPS samples to provide an estimate of survival from egg to larva. From 1988-1992 the ratio averaged 0.037; 1987 was excluded because of plant shutdown. Since fecundity has apparently not been studied for cunner (Auster 1989), a value of 100,000 was assumed for average lifetime fecundity. These two values provided a larva-to-adult survival rate of 0.0005. Applying the egg-to-larva and larva-to-adult survival rates to the numbers entrained produced estimated adult values ranging from 17,663 to 94,686 with an average of 54,763 (Table 3).

Cunner have no commercial value and little recreational importance so that current landing records are not available. To shed some light on their abundance in the PNPS area, calculations were performed to estimate the number of adult cunner which would be necessary to produce the number of eggs found there. The PNPS area was defined by Cape Cod Bay sampling stations 2,3,4,7,8 (MRI 1978), the half-tide volume of which was estimated by planimetry from NOAA chart 1208 at 22,541,000 100 m^3 units. Labrid egg densities were obtained at those stations on a weekly basis in 1975; they were integrated over time (April-December) using the mean density of the five stations. The integrated values were multiplied by 1.6 to account for extrusion through the 0.505-mm mesh used in that survey, then by the sector volume. The resulting value was divided by 2.2, the estimated incubation time in days for cunner eggs, then divided by 30,000, an estimate of mean annual fecundity per female. Lastly the resulting value was multiplied by 2 assuming an even sex ratio. These calculations resulted in an estimated production of 6.899 E 12 eggs and 209,064,000 adult fish. The loss of 54,763 fish represents 0.03% of that value.

<u>Atlantic mackerel</u>. Procedures outlined by Vaughan and Saila (1976) were used to derive a survival rate for mackerel eggs to age I fish (2.952 E-6). Using the observed ratio of eggs to larvae for PNPS of 0.0395 (1988-1992), a larva-to-age I survival rate of 7.473

Table 2. Numbers of larval winter flounder entrained at PNPS annually, 1987-1992. Number of equivalent age III adults is also shown for each year.

Year	Total Number Entrained ($x10^6$)	Equivalent Age III Adults
1987	3.49	215
1988	17.88	1102
1989	6.84	422
1990	7.96	491
1991	9.80	604
1992	8.42	519
Mean	9.07	559*

*Annual average would increase to 628 fish if 1987 were excluded due to absence of April sampling.

Table 3. Numbers of cunner eggs and larvae entrained at PNPS annually, 1987-1992. Number of equivalent adult fish is also shown for each year.

Year	Total Number Entrained ($x10^6$) Eggs	Larvae	Equivalent Adults
1987	3601.26	0.75	67,178
1988	1241.20	6.52	26,285
1989	3604.37	44.18	88,950
1990	1077.46	149.40	94,686
1991	544.36	15.13	17,663
1992	1753.76	2.57	33,815
Mean	1970.40	36.42	54,763

E-5 was calculated. Age-specific fecundity and instantaneous mortality necessary for these calculations was obtained from Griswold and Silverman (1992), Overholtz et al. (1988), and NOAA (1991). According to NOAA (1991) stock biomass consists of fish age I and older while fish completely recruit to the spawning stock by age III. Therefore, adult equivalent values are shown for both age groups (Table 4). Annual values averaged 6496 age I and 4355 age III fish. These convert to 1299 and 3049 pounds based on weights of 0.2 and 0.7 pounds per individual (Clayton et al. 1978).

According to NOAA statistical records, an annual average of 443,195 pounds of mackerel were taken commercially from statistical area 514 from 1982-1991. The age I and III adult equivalent estimates represent 0.3 and 0.7% of those landings.

The effects of entrainment on populations of Atlantic menhaden, winter flounder, pollock (Pollachius virens), cunner, rainbow smelt (Osmerus mordax), Atlantic silversides (Menidia menidia), and alewives (Alosa pseudoharengus) were assessed by Stone and Webster (1975) using flow rates for two units at Pilgrim Station. Using conservative assumptions and ignoring density-dependent compensation among non-entrained ichthyoplankton, no appreciable adverse impact on indigenous populations was predicted to occur. Modeling studies conducted on five species of larval fish which appear to be more abundant in western Cape Cod Bay than in the remainder of the Bay (tautog; seasnail, Liparis spp.; radiated shanny, Ulvaria subbifurcata; sculpin, Myoxocephalus spp.; and rock gunnel) suggested that the percentage of original larval

Table 4. Numbers of Atlantic mackerel eggs and larvae entrained at PNPS annually, 1987-1992. Numbers of equivalent age I and III fish are also shown for each year.

Year	Total Entrained ($x10^6$)		Equivalent Adults	
	Eggs	Larvae	Age I	Age III
1987	75.09	0.28	243	163
1988	2378.22	3.40	7275	4876
1989	4173.14	65.56	17219	11542
1990	2065.55	46.27	6443	4319
1991	428.36	66.01	6197	4154
1992	337.15	8.09	1600	1073
Mean	1576.25	31.60	6496	4355

production contributing to entrainment by PNPS Unit 1 was less than 1.0 for each species (MRI 1978). For twelve additional categories of eggs and larvae (see MRI 1978) considered to be more widely distributed in Cape Cod Bay, percentages contributing to entrainment were smaller, the highest being 0.12% (labrid-*Pleuronectes* eggs).

If entrainment of ichthyoplankton at PNPS represented a significant source of mortality in western Cape Cod Bay, the losses might be reflected in finfish collections in the PNPS area. A review of indices of relative abundance for some species based on otter trawl and gill net sampling by Massachusetts Division of Marine Fisheries personnel (Lawton et al. 1990; V.J. Malkoski, personal communication) does not indicate any long-term steady declines among Atlantic herring, pollock, or tautog. Several species, on the other hand, have displayed recent declines in abundance. These include cunner, windowpane (*Scophthalmus aquosus*), yellowtail flounder, and winter flounder. In these cases, however, commercial landings, stock assessment research, and other monitoring studies indicate that these declines appear to be widespread, extending all along the Massachusetts coastline (MDMF 1985, Foster 1987, Howe et al. 1988, NOAA 1991, MRI 1991). Therefore, these specific declines appear to be the result of natural population variation probably coupled with overfishing, rather than PNPS impact.

D. Potential Pump Effects

PNPS was involved in a long-term outage which began in April 1986 and continued into 1989. During most of this period only one of two main circulating water system (CWS) pumps was operating (flow = 155,000 gpm, 9.78 m^3 per second, compared with 310,000 gpm or 19.56 m^3 per second, when the plant operates with two pumps). Beginning in late March 1987, intermittent use of a single circulating seawater pump made it basically unavailable for entrainment sampling, leaving only one or occasionally two Salt Service Water System (SSWS) pumps in service, each with a capacity of about 2500 gpm, or 0.16 m^3 per second. From May through early September 1987 sampling continued with only the SSWS pump(s) providing flow for entrainment sampling. This situation also occurred from April through late August 1984 although two SSWS pumps functioned throughout that period. During periods when sampling was completed with only SSWS pumps, ichthyoplankton densities appeared to be exceptionally low, particularly among larvae.

During recent years the apparent influence of different pump regimes on densities of ichthyoplankton have been compared over the months of April-August (see MRI 1988-1991). Results strongly suggest that larvae and to a lesser extent eggs are entrained in direct proportion to plant pumping rates. With the 1992 data base in hand these analyses were extended to determine if the relationship between densities and pumping rates remained con-sistent and clear. The 1991 data set complicated the analyses because two CWS pumps were operating during April and August while only one operated during May, June, and July. This effectively reduced the data base for portions of the analysis to three months rather than four. To compare the response of ichthyoplankton to different pump regimes, densities per 100 m^3 of water were compared for single SSWS pump periods (1987), two SSWS pump periods (1984), single CWS pump periods (1986, 1988), and two CWS pump periods (1983, 1985, 1990, 1992). Statistical comparisons involving these data were initially restricted primarily to the May through August time frame when sampling was possible and the stated pump schedules were consistently maintained; the 1987 data set forced the exclusion of April from the statistical tests because no sampling occurred in April 1987 due to uncertainty concerning the pump use schedule at that time. The 1991 data set reduced statistical treatment to May through July. April and August data from all years analyzed were included in graphical analyses however. The 1991 data were simply divided, April and August averaged with two-CWS-pump years, May-July with one-CWS-pump years. Collections made between April and August 1989 did not fall clearly into any specific pump use category because the plant was returning to service, and CWS pump operation varied between one and two pumps. Only June and August 1989 were consistently sampled under one regime (all pumps in service).

When collections were first made in 1984 using the relatively low-volume SSWS pumps, an assumption was made that ichthyoplankton would continue to be sampled in proportion to its abundance in the

Rocky Point area since larval fishes, especially the small ones, show little directional swimming ability and pelagic eggs certainly drift passively. Results reported in the 1986 annual PNPS report (MRI 1987) indicated that April-August 1984 larval entrainment collections (2 SSWS pumps only) were so low that local populations did not appear to be impacted in similar proportion by the SSWS pumps as by the CWS pumps. When 1987 larval data became available, the limited influence of the SSWS pumps became more apparent. May-August larval densities for 1987 when only one SSWS pump was used were exceptionally low each month, even when compared with 1984. Egg densities in 1987 ranked lowest over the 1983-1987 period only for August.

Mean densities per 100 m^3 of water for total eggs and total larvae, May-July 1983-1992 were examined using a nonparametric, single classification, Kruskal-Wallis test; data obtained on May 30 and June 25, 1987 were omitted because those samples were taken during brief periods of single CWS pump operation. For the Kruskal-Wallis test individual sampling dates were used in a balanced design. No significant difference was apparent among years for eggs ($p = 0.05$) but a very highly significant difference ($p < 0.001$) was found for larvae. Nonparametric multiple comparisons among years for larvae showed years falling into five groups. No significant difference ($p > 0.05$) was apparent among 1990, 1989, 1985, and 1983, the four years when the circulating water system operated at full capacity for all or a good portion of the season. Significantly different from this group ($p < 0.05$) was a second composed of 1992, 1991, and 1986. With the exception of 1992 this group consisted of years when one CWS pump was out of service. Data for 1988 (1 CWS pump) fell between those two groups. The last two groups consisted of 1984, the two SSWS year, and 1987, the one SSWS year, both significantly different from the two and one CWS pump groups ($p < 0.05$) and from each other ($p < 0.001$). The summed ranks as well as results of the multiple comparisons (indicated by vertical bars) were as follows:

May-July 1983-1992			
RANK SUM EGGS	PUMPS	RANK SUM LARVAE	PUMPS
1989 - 768	(ALL or 1 CWS O.O.S.)	1990 - 850	(ALL)
1988 - 741	(1 CWS O.O.S.)	1989 - 820	(ALL or 1 CWS O.O.S.)
1985 - 655	(ALL)	1983 - 748	(ALL)
1983 - 639	(ALL)	1985 - 705	(ALL)
1990 - 615	(ALL)	1988 - 638	(1 CWS O.O.S.)
1986 - 556	(1 CWS O.O.S.)	1986 - 537	(1 CWS O.O.S.)
1992 - 550	(ALL)	1992 - 532	(ALL)
1987 - 501	(1 SSWS)	1991 - 520	(1 CWS O.O.S.)
1991 - 442	(1 CWS O.O.S.)	1984 - 395	(2 SSWS)
1984 - 420	(2 SSWS)	1987 - 142	(1 SSWS)
10.09 n.s.	Kruskal-Wallis Coefficient		37.26*** ($p < 0.001$)

O.O.S. = Out Of Service

Figure 3 presents the monthly means averaged within pump operation categories for the April-August time frame. Data for May-August 1990 were averaged with the corresponding data from 1983 1985, and 1992, the years of full operation. Data for April 1990 when only one CWS pump was in service were averaged with April 1986 and 1988. Similarly April and August 1991 were averaged with 1983, 1985, 1990, and 1992 when all pumps operated; May, June, July were averaged with 1986 and 1988, periods with one CWS pump. Larval

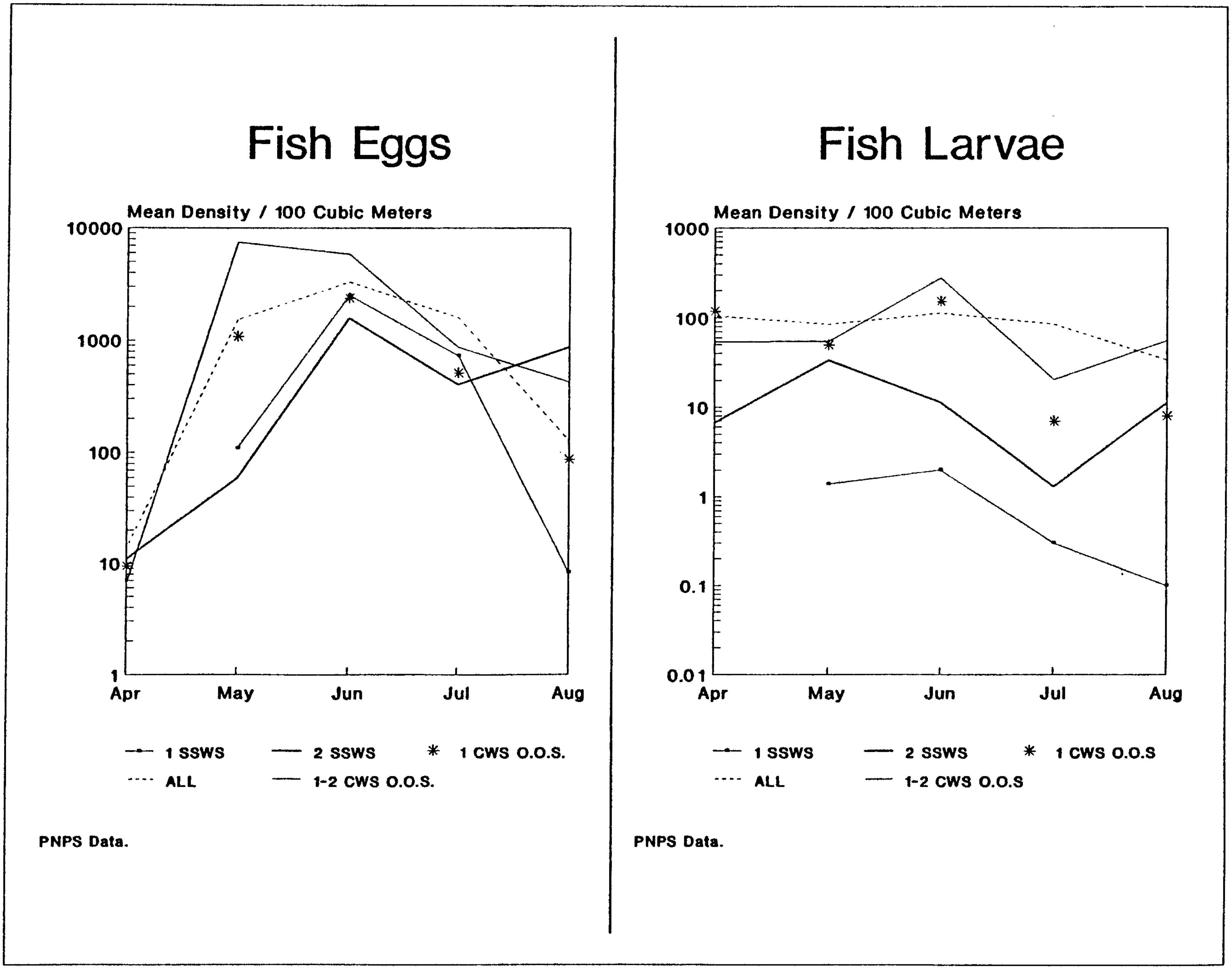

Figure 3. Mean monthly densities per 100 m^3 of water for total eggs and total larvae entrained at PNPS within four pump operation categories during the April-August period of 1983-1992. See text for details.

densities separated distinctly, particularly when sampling occurred only with one or two salt service water pumps. Data for 1989 with mixed pump usage varied between the all and one CWS pump regimes but in a consistent manner. June and August with all pumps in service during each sampling period ranked above the other years. May and July with two of five and one of four dates with all pumps in service, respectively, showed monthly means which fell between the all and one CWS pump values. April, also having one of four dates with all pumps operating, fell below the one and all CWS pump category but well above the two SSWS pumps mean for that month.

The fact that 1989 ranked second overall for the May-July period in spite of the six dates when one CWS pump was out of service, suggests that in general larvae were relatively abundant during that period. In contrast, the relatively low ranking of 1992, an all pump operational year, suggests larval densities were low at that time. The May-July 1991 period ranked low also, lowest among the 1 CWS pump years. A review of monthly densities in Apendix B indicates that larval densities overall were noticeably low in July 1991 and 1992 due to relatively low numbers of rockling, cunner, and mackerel.

The apparent reduced susceptibility of larvae to the SSWS pumps was further indicated by sampling on May 30, 1987 when collections were made while one CWS pump was placed into service for a short period. On May 28 no larvae were obtained while sampling under the influence of one SSWS pump. Two days later on May 30 a mean density of 132 larvae per 100 m^3 was obtained consisting of eight species. On June 4, again with only one SSWS pump operating, two larval species with a combined mean density of 2 per 100 m^3 of water were taken.

A comparison of the number of ichthyoplankton species recorded from May through July over the 1983-1992 period indicated that 1987, with one SSWS pump operating, was clearly the lowest with 13 overall (22 with inclusion of the three dates when one CWS pump was in use); 1984 (2 SSWS pumps) followed with 25. Numbers of species ranged from 29 (1986) to 34 (1989) during years when at least one CWS pump was in use. The low species count in 1987 was due primarily to a scarcity of larvae. Only six species of larvae were recorded over the May-July period of 1987 compared with 16 (1984) to 30 (1985, 1989) over the other years. Omitting 1984 when both CWS pumps were off, raises the low end larval species count from 16 to 24 (1991). Numbers of egg species were somewhat more consistent with 12 being taken in 1987 compared with 14 (1988) to 20 (1991) during the other years. Including May 30 and June 25, 1987 when a single CWS pump was in service brought the 1987 totals up to 14 species of eggs and 14 species of larvae.

The low densities of larvae in 1984 and the strikingly low densities in 1987 over the spring and early-summer period strongly suggest that ichthyoplankton populations near PNPS were not impacted in similar proportion by the SSWS pumps as by the main circulating seawater pumps. A sharp decline in larval densities occurred between 1984 (16) and 1987 (6), suggesting that dropping from two to one SSWS pump eliminated entrainment of many larvae.

The intermediate values for 1986, 1988, and 1991 when one CWS pump was in service, ranking between 1984/1987 and 1983/1985/1990 suggests a direct relationship between pump flow and larval entrainment. Values for 1989 with variable pump operation further support this conclusion (Figure 3). Apparently the relatively low flow of the SSWS pumps has very limited influence on drawing larvae into the intake embayment area and subsequently through the PNPS condensers. These results could reflect mainly physical flow effects acting upon free-floating larvae or perhaps an active larval swimming ability, permitting an increasing number of them to avoid entrainment as pump capacity declines. For example, at some point water entrained by the PNPS intake separates from the prevailing Cape Cod Bay current and enters the intake area. The area over which the flow separation occurs is presumably more widespread and the action more forceful (the velocity higher) when two seawater pumps operate than when only one seawater pump operates, or even when one or two SSWS pumps operate. Passive larvae and eggs should be entrained in proportion to their abundance, but more active larvae may swim, to the extent of their ability, to remain within the Cape Cod Bay water mass. Also the more widespread the influence of a particular pumping rate, the higher the probability that high-density ichthyoplankton patches will be entrained. The role which vertical distribution plays may be of great importance as well, as the smaller pumps probably draw water over a more restricted vertical profile, one which may not coincide with the presence of many eggs and larvae.

Although no significant difference was detected among years for total eggs, years did rank in similar manner to the larvae. Notable exceptions occurred with 1988 (one CWS pump) which ranked second among the eggs and 1992 (2 CWS pumps) which ranked fourth among the fully operational years and seventh overall. The one SSWS and two SSWS pump years (1984 and 1987) again ranked low. As mentioned for larvae, the high ranking of 1989 among the eggs taken from May through July, when one CWS pump was out of service on six occasions, suggests that eggs were generally abundant during those months. Likewise the low ranking of 1991 eggs when only one CWS pump was out of service suggests egg densities were low that May-July period.

It is important to keep in mind that all comparisons based on different pump capacities were made without knowledge of ichthyoplankton populations around Rocky Point. The observed rankings could have been due entirely, or in part, to differences in production among the ten years, although that would appear to be an extraordinary coincidence given the well-defined relationship between ichthyoplankton densities and PNPS flow. Perhaps, on the contrary, the fact that densities ranked according to pump capacity in spite of high inter-year variability suggests how strong the relationship may be.

E. Lobster Larvae

The scarcity of larval lobsters (*Homarus americanus*) in PNPS entrainment samples continues to present an interesting question considering the productive lobster fishery that exists in the area.

According to Massachusetts Division of Marine Fisheries statistics, annual landings in Plymouth County by fishermen working inshore waters have averaged 1370 tons and 7.5 million dollars from 1985-1991 (see for example, McCarron and Hoopes 1992).

Neuston sampling conducted in the northwest sector of Cape Cod Bay (Lawton et al. 1983; Matthiessen and Scherer 1983) also indicated that larvae were not particularly abundant there. To support such a strong fishery it would appear young lobsters must arrive in the Plymouth area from other regions. Sampling around Rocky Point from 1974 through 1977 showed considerably more late-stage larvae than young larvae (Lawton et al. 1983). That, coupled with the prevailing counterclockwise Cape Cod Bay currents, suggests that larvae may arrive from the north. Sampling at the mouth of the Cape Cod Canal also suggests that large numbers of larvae enter Cape Cod Bay from Buzzards Bay and perhaps the Canal itself (Matthiessen and Scherer 1983; Matthiessen 1984). Regardless of source, larval lobsters appear to be especially uncommon in PNPS entrainment samples. This is supported by Lawton et al. (1983) who caught only eight larvae in twenty neuston tows near shore around Rocky Point in 1975. In addition to their apparent scarcity in near-shore waters, larval lobsters' neustonic habits may reduce the probability of their entrainment since they would contact the PNPS intake skimmer wall which might prevent some from passing to the condensers. Reduced intake flow during the summer of 1984, and the extended outage period covering the 1986-1989 larval seasons no doubt lowered the probability of lobster entrainment even further.

SECTION IV

HIGHLIGHTS

1) Ichthyoplankton densities in the PNPS discharge canal meeting the "unusually abundant" criterion defined under the contingency sampling plan did not occur in 1992.

2) Total numbers of eggs and larvae which may have been entrained by PNPS in 1992 were estimated to range from 426,059 for Atlantic menhaden eggs to 1,753,758,934 for labrid-yellowtail eggs and from 2,222,841 for sea snail larvae to 108,323,789 for sand lance larvae.

3) Annual adult equivalent estimates for PNPS ichthyoplankton entrainment losses to cunner, mackerel, and winter flounder populations from 1987-1992 averaged 54,763, 6496, and 628 fish, respectively.

4) Analysis of entrainment data collected from April through August 1983-1992 strongly suggests that larvae and to a lesser extent eggs are entrained in direct proportion to plant pumping rates.

5) No larval lobsters were collected in PNPS entrainment samples in 1992. The low numbers taken in discharge samples remains surprising considering the strong commercial lobster fishery in the area.

SECTION V

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IMPINGEMENT OF ORGANISMS AT

PILGRIM NUCLEAR POWER STATION

(January - December 1992)

Prepared by: Robert D. Anderson

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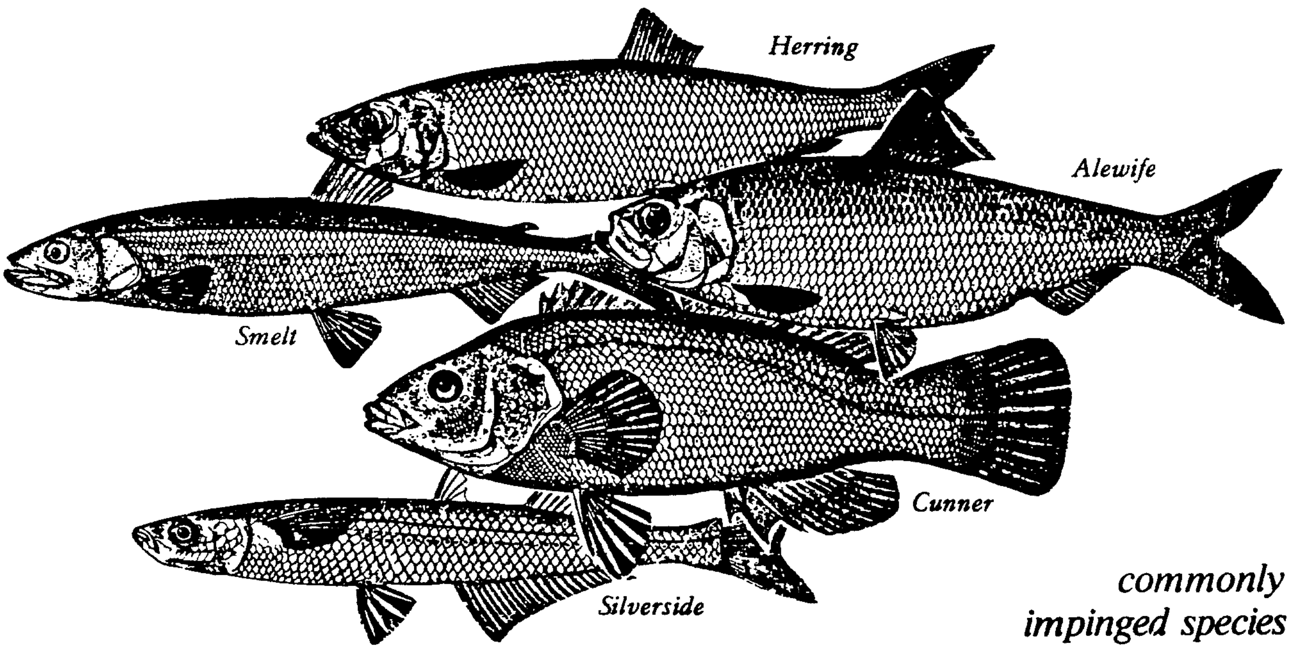
Licensing Division

Boston Edison Company

April 1993



commonly impinged species

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SECTION I

SUMMARY

Fish impingement rate averaged 0.63 fish/hour during the period January-December 1992, which is several times lower than 1991 when there was a large impingement incident. Atlantic silverside (Menidia menidia) accounted for 47.3% of the fishes collected. Winter flounder (Pleuronectes americanus), grubby (Myoxocephalus aeneus), and rainbow smelt (Osmerus mordax) accounted for 14.7, 8.8 and 5.1%, respectively, of the fishes impinged. The peak period was February - March when Atlantic silverside accounted for an estimated 1,622 of the fishes on the intake screens. Initial impingement survival for all fishes from static screen wash collections was approximately 45%, and from continuous screen washes 47%.

At 100% yearly (January-December) operation of Pilgrim Nuclear Power Station (PNPS) the estimated impingement was 5,572 fishes (204 lbs.). The PNPS capacity factor was 80.6% during 1992.

The collection rate (no./hr.) for all invertebrates captured from January-December 1992 was 0.76. Sevenspine bay shrimp (Crangon septemspinosa), horeshoe crab (Limulus polyphemus) and American lobster (Homarus americanus) were most numerous, accounting for 48.4, 13.6 and 11.8%, respectively, of the invertebrates impinged. Mixed species of algae collected on intake screens amounted to 5,261 pounds.

SECTION 2

INTRODUCTION

Pilgrim Nuclear Power Station (lat. 41°56′ N, long. 70°34′ W) is located on the northwestern shore of Cape Cod Bay (Figure 1) with a licensed capacity of 670 MWe. The unit has two circulating water pumps with a capacity of approximately 345 cfs each and five service water pumps with a combined capacity of 23 cfs. Water is drawn under a skimmer wall, through vertical bar racks spaced approximately 3 inches on center, and finally through vertical travelling water screens of 3/8 inch wire mesh (Figure 2). There are two travelling water screens for each circulating water pump.

This document is a report pursuant to operational environmental monitoring and reporting requirements of NPDES Permit No. 0003557 (USEPA) and No. 359 (Mass. DWPC) for Pilgrim Nuclear Power Station, Unit I. The report describes impingement of organisms and survival of fishes carried onto the vertical travelling water screens at Unit I. It presents analysis of the relationships among impingement, environmental factors, and plant operational variables.

This report is based on data collected from screen wash samples during January-December 1992.

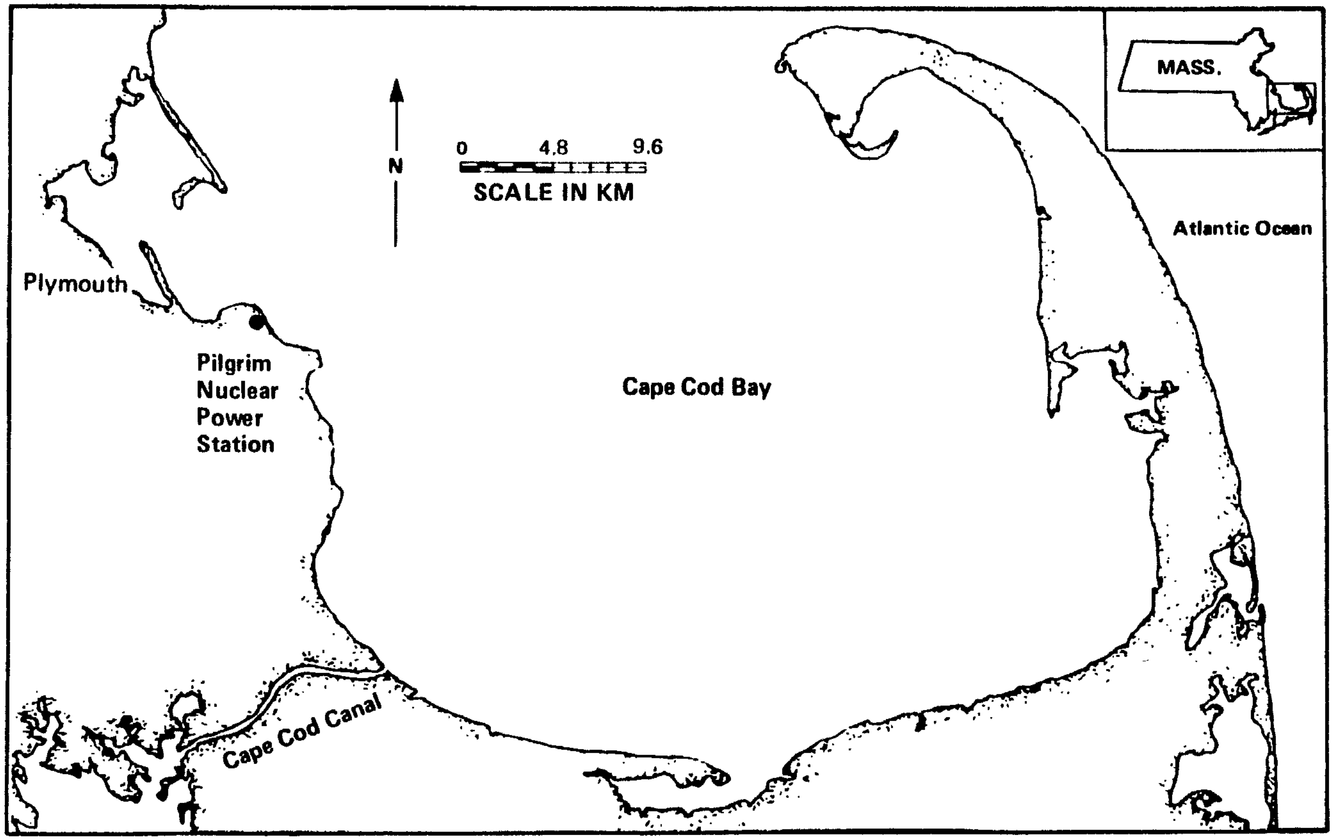

Figure 1. Location of Pilgrim Nuclear Power Station.

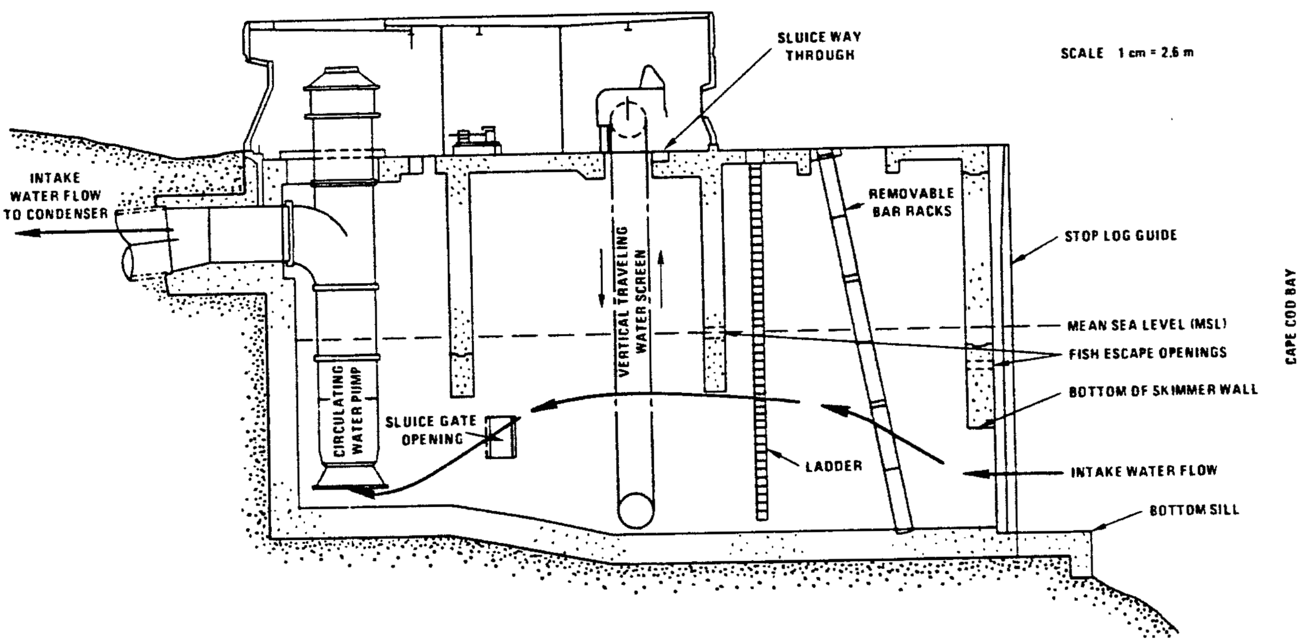

Figure 2: Cross-section of intake structure of Pilgrim Nuclear Power Station.

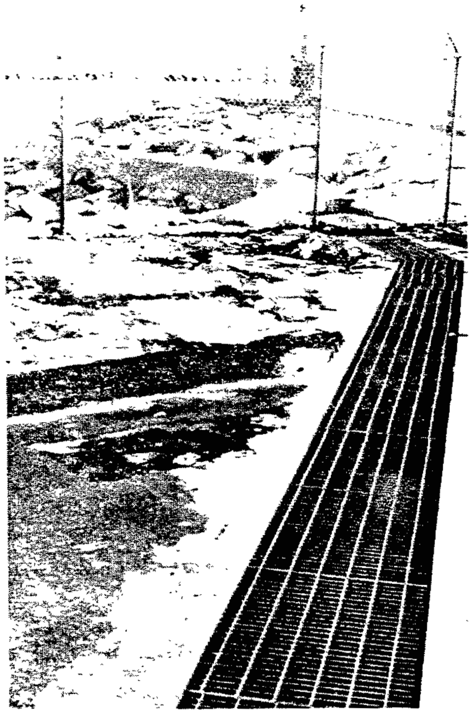

Plate 1. The 300 foot long Pilgrim Station, concrete screenwash sluiceway is molded from 18" corrugated metal pipe, and meanders over breakwater rip rap.

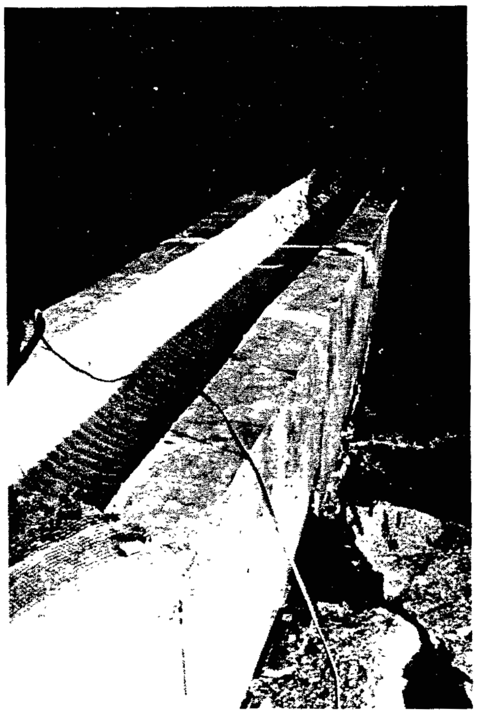

Plate 2. Fish survival testing is done at the end of the sluiceway where it discharges to ambient temperature intake waters.

SECTION 3

METHODS AND MATERIALS

Three screen washings each week were performed from January-December 1992 to provide data for evaluating the magnitude of marine biota impingement. The total weekly collection time was 24 hours (three separate 8-hour periods: morning, afternoon and night). Two collections represented dark period sampling and one represented light period sampling. At the beginning of each collection period, all four travelling screens were washed. Eight hours later, the screens were again washed (minimum of 30 minutes each) and all organisms collected. When screens were being washed continuously, one hour collections were made at the end of the regular sampling periods, and they represented two light periods and one dark period on a weekly basis.

Water nozzles directed at the screens washed impinged organisms and debris into a sluiceway that flowed into a trap. The original trap was made of galvanized screen (3/8-inch mesh) attached to a removable steel frame and it collected impinged biota shortly after being washed off the screens. A second trap was designed and used for sampling consisting of a section of half 18" corrugated metal pipe with 3/16-inch nylon, delta mesh netting attached. Impinged biota sampled by this trap were collected at the end of a 300′ sluiceway. Initial fish survival was determined for static (8-hour) and continuous screenwash cycles. Plates 1 and 2 provide views of the beginning and end of the sluiceway structure which was constructed in 1979.

Variables recorded for organisms were total numbers, and individual total lengths (mm) and weights (gms) for up to 20 specimens of each species. A random sample of 20 fish or invertebrates was taken whenever the total number for a species exceeded 20; if the total collection for a species was less than 20, all were measured and weighed. Field work was conducted by Marine Research, Inc.

Intake seawater temperature, power level output, tidal stage, number of circulating water pumps in operation, time of day and date were recorded at the time of collections. The collection rate (#/hour) was calculated as number of organisms impinged per collecting period divided by the total number of hours in that collecting period. Beginning in 1990, if all four intake screens are not washed for a collecting period then the number of fishes collected is increased by a proportional factor to account for the unwashed screens, as requested by the Pilgrim Administrative-Technical Committee. Common and scientific names in this report follow the American Fisheries Society (1988, 1989, 1991a and 1991b) or other accepted authority when appropriate.

SECTION 4

RESULTS AND DISCUSSION

4.1 Fishes

In 774 collection hours, 491 fishes of 32 species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January - December 1992. The collection rate was 0.63 fish/hour. This annual impingement rate is several times lower than last year, primarily because of a large impingement incident of over 4,000 Atlantic herring (*Clupea harengus harengus*) from July 22-25, 1991. Atlantic silverside was the most abundant species in 1992, accounting for 47.3% of all fishes collected (Table 2). Winter flounder (*Pleuronectes americanus*), grubby (*Myoxocephalus aeneus*) and rainbow smelt (*Osmerus mordax*) accounted for 14.7, 8.8 and 5.1% of the total number of fishes collected and identified to lowest taxon.

Atlantic silverside occurred most predominantly in monthly samples from February and March. Hourly collection rates per month for them ranged from 0 to 1.54. Atlantic silverside impinged in February and March accounted for 77% of all this species captured in impingement collections from January-December 1992. They averaged 109 mm total length and 5 grams in weight. Their impingement indicated no relationship to tidal stage or diel factors. It is not unusual for them to be the dominant fish in the annual impingement catch, as they have been for 9 out of the past 12 years. A review of historical data shows them to be impinged in greatest numbers during early spring when they were well represented in 1992, being most prevalent in March of that year. Some other relatively abundant species impinged at Pilgrim Station over the past 10 years are also documented in Table 3.

Table 1. Monthly Impingement For All Fishes Collected From Pilgrim Station Intake Screens, January-December 1992

Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
Atlantic silverside	26	55	123	25	2						1		232
Winter flounder	9	16	4	8		3	1					31	72
Grubby	17	7	4	2	2			1			3	7	43
Rainbow smelt	9	1			3				1		2	9	25
Alewife	1		1	4	2					2	7	5	22
Atlantic tomcod		2			1						6	2	11
Blueback herring			2								1	8	11
Lumpfish	1				1			2		2		4	10
Tautog										1	2	6	9
Little skate					2		1	4			1		8
White perch	5	1	1										7
Striped killifish	1								1		2		4
Atlantic herring					3								3
Cunner		1					1	1					3
Radiated shanny		1			2								3
Rock gunnel				1						1		1	3
Windowpane		1							1			1	3
Atlantic menhaden								1	1				2
Atlantic seasnail		1										1	2
Northern pipefish										2			2
Northern puffer									2				2
Sand Lance sp.							1					1	2
Scup									1			1	2
Threespine stickleback		1			1								2
American eel							1						1
Atlantic cod												1	1
Atlantic moonfish										1			1
Black sea bass										1			1
Planehead filefish										1			1
Pollock					1								1
Red hake										1			1
Silver hake		1											1
TOTALS	69	88	135	40	20	3	5	9	7	12	25	78	491
Collection Time (hrs.)	53	78	80	53	44	55	92	70	34	54	90	71	774
Collection Rate (#/hr.)	1.30	1.13	1.69	0.75	0.49	0.05	0.05	0.13	0.21	0.22	0.28	1.10	0.63

Table 2. Species, Number, Total Length(mm), Weight(gms) and Percentage For All Fishes Collected From Pilgrim Station Impingement Sampling, January-December 1992

Species	Number	Length Range	Mean Length	Weight Range	Mean Weight	Percent of Total Fish
Atlantic silverside	232	79-145	109	2-15	5	47.3
Winter flounder	72	47-346	108	1-253	35	14.7
Grubby	43	49-121	74	1-27	7	8.8
Rainbow smelt	25	93-173	126	3-38	12	5.1
Alewife	22	72-202	113	3-47	12	4.5
Atlantic tomcod	11	106-170	123	8-57	18	2.2
Blueback herring	11	76-124	100	3-11	7	2.2
Lumpfish	10	34-80	48	1-18	5	2.0
Tautog	9	58-120	78	3-32	12	1.8
Little skate	8	241-507	411	70-750	503	1.6
White perch	7	110-155	123	15-54	23	1.4
Striped killifish	4	76-84	81	5-7	6	0.8
Atlantic herring	3	42-45	43	0.2-0.4	0.3	0.6
Cunner	3	49-160	113	2-56	35	0.6
Radiated skanny	3	101-137	116	6-20	13	0.6
Rock gunnel	3	62-144	90	1-8	3	0.6
Windowpane	3	88-102	94	9-10	9	0.6
Atlantic menhaden	2	76-270	173	3-226	115	0.4
Atlantic seasnail	2	45-79	62	1-7	4	0.4
Northern pipefish	2	126-167	157	1-2	2	0.4
Northern puffer	2	38-67	53	2-7	5	0.4
Sand lance sp.	2	80-125	103	1-7	4	0.4
Scup	2	42-110	76	1-17	9	0.4
Threespine stickleback	2	58-64	61	1-2	2	0.4
American eel	1	585	585	210	210	0.2
Atlantic cod	1	105	105	8	8	0.2
Atlantic moonfish	1	52	52	2	2	0.2
Black sea bass	1	83	83	7	7	0.2
Planehead filefish	1	170	170	17	17	0.2
Pollock	1	72	72	3	3	0.2
Red hake	1	190	190	53	53	0.2
Silver hake	1	134	134	14	14	0.2

Table 3. Annual Impingement collections (1983 -1992) For the 10 Most Abundant Fishes From Pilgrim Station Intake Screens During January - December 1992

Number of Impinged Fishes Collected From January - December

Species	1983	1984*	1985	1986	1987**	1988***	1989	1990	1991	1992	Totals
Atlantic silverside	97	22	174	44	27	35	120	457	275	232	1,483
Winter flounder	20	5	39	76	10	11	42	31	67	72	373
Grubby	38	15	36	30	5	5	29	59	46	43	306
Rainbow smelt	57	5	8	278	41	11	39	38	41	25	543
Alewife	8	12	37	25	4	8	8	131	24	22	279
Atlantic tomcod	17	12	18	16	5	31	17	26	16	11	169
Blueback herring	59	5	17	5	1	2	15	103	31	11	249
Lumpfish	9	13	5	5	10	8	3	8	5	10	76
Tautog	2	2	2	2	5	2	12	6	18	9	60
Little skate	4	2	2	1	4	1	5	0	8	8	35
Totals	311	93	338	482	112	114	290	859	531	443	3,573
Collection Time (hrs)	763	1,042	465	806	527	525	618	919.5	501.25+	774	6,940.75+
Collection Rate (#/hr)	0.41	0.09	0.73	0.60	0.21	0.22	0.47	0.93	1.06	0.57	0.51

*No CWS pumps were in operation 29 March - August 1984.
**No CWS pumps were in operation 18 February - 8 September 1987.
***No CWS pumps were in operation 14 April - 5 June 1988.

Winter flounder were relatively prevalent in December-February samples, possibly indicative of this species seasonal inshore spawning movements. It has been one of the more commonly impinged fish over the years.

Grubby were impinged most in the winter and have historically been collected in relatively low numbers, although its year-round presence in the Pilgrim Station area is apparent.

Rainbow smelt were relatively abundant in the December/January impingement collections and have been most prevalent in the late fall/early winter period, ranking first in 1978 and 1987 in total numbers impinged. It has been common for them to rank highly in impingement (Table 3).

Alewife (Alosa pseudoharengus) (4.5% of the catch) occurred predominantly in November/December when 55% of them were sampled, not reflecting this species historical nature for maximum impingement in the summertime. It has been one of the most impinged fish, although not dominating the annual catch.

Monthly intake water temperatures and impingement rates for the five dominant species in 1992 are illustrated in Figure 3.

There was no fish impingement incident (20 fish or greater/hr.) at Pilgrim Station in 1992. All large fish impingement mortalities (> 1,000 fish) have occurred while both circulating water pumps were operating. Eleven large fish incidents have been documented since Pilgrim operation commenced in 1973, and most (7) have involved impingement as the causative agent (Table 4).

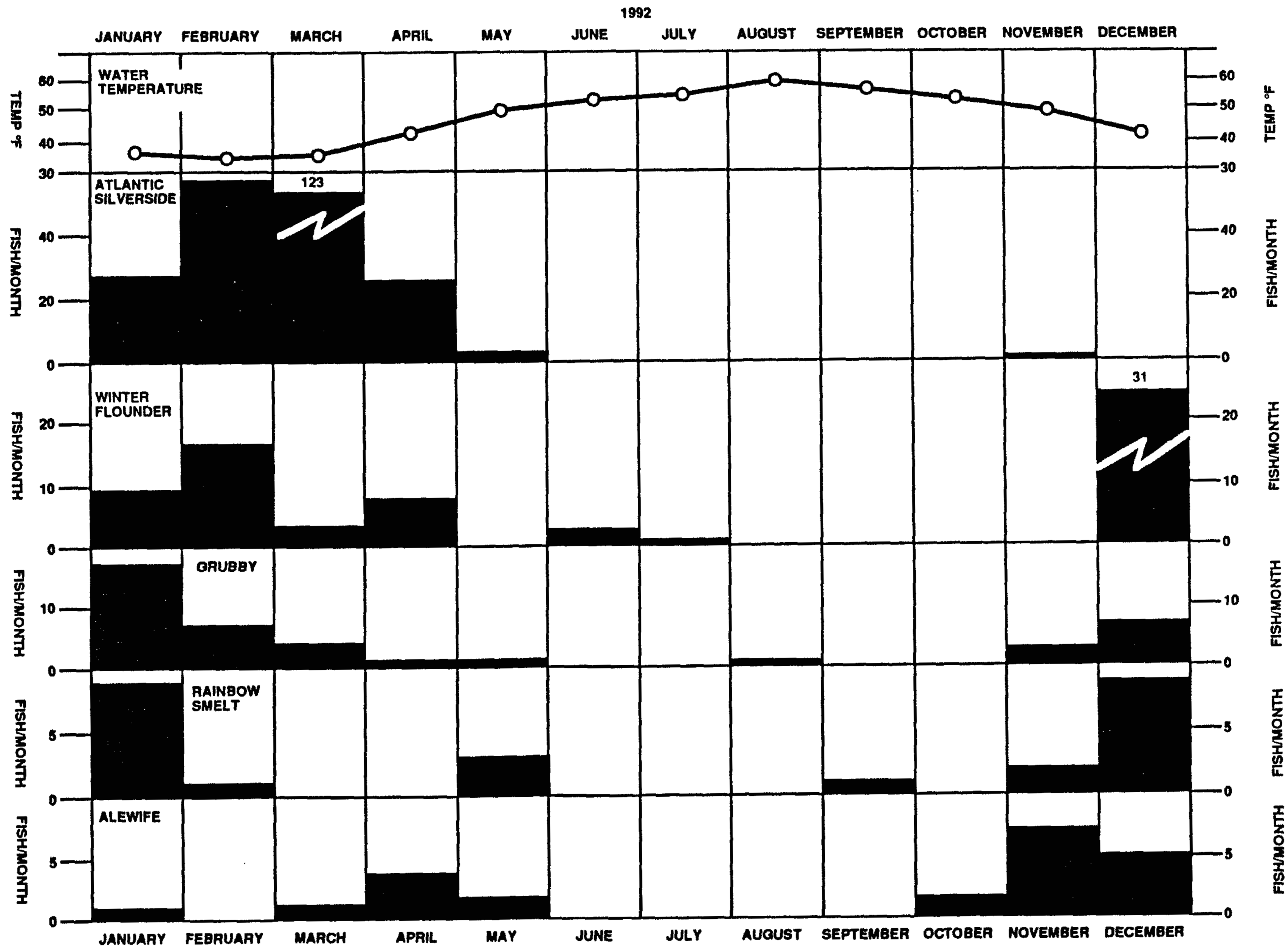

Figure 3. Trends of Intake Water Temperature, and Number of Fish Captured by Month from Pilgrim Station Intake Screens for the Five Most Abundant Species Collected, January-December 1992.

Table 4. Approximate Number and Cause for Most Notable Fish Mortalities at Pilgrim Nuclear Power Station, 1973-1992

Date	Species	Number	Cause
April 9-19, 1973	Atlantic Menhaden	43,000	Gas Bubble Disease
August/September, 1973	Clupeids	1,600	Impingement
April 2-15, 1975	Atlantic Menhaden	5,000	Gas Bubble Disease
August 2 1975	Atlantic Menhaden	3,000	Thermal Stress
August 5 1976	Alewife	1,900	Impingement
November 23-28, 1976	Atlantic Herring	10,200	Impingement
August 21-25, 1978	Clupeids	2,300	Thermal Stress
December 11-29, 1978	Rainbow Smelt	6,200	Impingement
March/April, 1979	Atlantic Silverside	1,100	Impingement
September 23-24, 1981	Atlantic Silverside	6,000	Impingement
July 22-25, 1991	Atlantic Herring	4,200	Impingement

However, at least in two of these the possibility of pathological influence was implicated as indirectly contributing to the mortalities. They were the Atlantic herring (tubular necrosis) and rainbow smelt (piscine erythrocytic necrosis) impingement incidents in 1976 and 1978, respectively.

Fish impingement rate at Pilgrim Station has been shown to be significantly related to the number of circulating water pumps operating (Lawton, Anderson et al, 1984b). Reduced water pumping capacity has lowered total impingement, particularly during the April-mid-August 1984 and portions of the mid-February-August 1987 periods when no circulating water pumps were operating for extended time frames. The significance of this relationship is supported by the fact that total fish impingement and rate of fish impingement were several times lower in 1984 and 1988 (low-pump year) than in 1985, 1986 and 1989 - 1992, despite a greater number of collecting hours in 1984 and an average number of hours in 1988. In 1987, far fewer collecting hours were possible when both circulating pumps were off than in these other years which limits comparisons to them. However, total fish impingement rates in 1984, 1987 and 1988 were several times lower than in 1985, 1986 and 1989 - 1992 when at least one circulating pump was always in operation. Figure 4 illustrates the relationship between fish impingement rate and number of circulating pumps operating which demonstrates, for the most part, the rate reduction effect of no pumps vs. 1 or 2 pumps.

Projected fish impingement rates were calculated assuming 100% operation of Pilgrim Nuclear Power Station, under conditions at the times of impingement, during the period January-December 1992. Table 5 presents hourly, daily and yearly impingement rates for each species captured (rates are rounded to

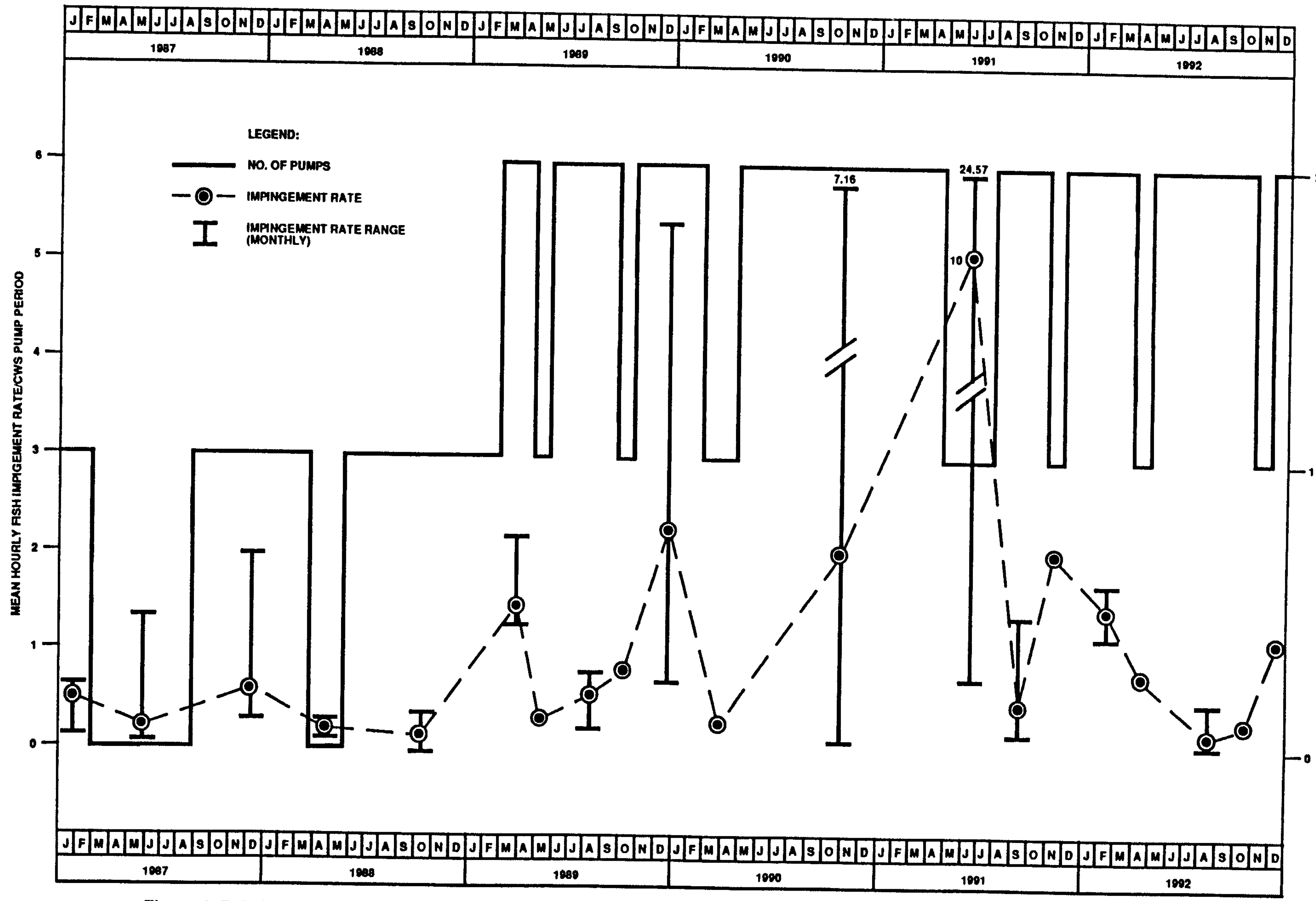

Figure 4. Relationship of Pilgrim Station Circulating Water System (CWS) Pumps' Operation (Pump Flow) to Fish Impingement Rate for the Period 1987-1992

Table 5. Impingement Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During January - December 1992. Assuming 100% Operation of Pilgrim Unit 1*

Species	Rate/Hr.	Rate/Day	Rate/January-December 1992*	Dominant Months Of Occurrence
Atlantic silverside	0.30	7.19	2,633	March
Winter flounder	0.09	2.23	817	December
Grubby	0.06	1.33	488	January
Rainbow smelt	0.03	0.78	284	December & January
Alewife	0.03	0.68	250	November
Atlantic tomcod	0.01	0.34	125	November
Blueback herring	0.01	0.34	125	December
Lumpfish	0.01	0.31	113	December
Tautog	0.01	0.28	102	December
Little skate	0.01	0.25	91	August
White perch	0.009	0.22	79	January
Striped killifish	0.005	0.12	45	November
Atlantic herring	0.004	0.09	34	May
Cunner	0.004	0.09	34	July & August
Radiated shanny	0.004	0.09	34	May
Rock gunnel	0.004	0.09	34	October & December
Windowpane	0.004	0.09	34	November
Atlantic menhaden	0.003	0.06	23	August & September
Atlantic seasnail	0.003	0.06	23	December & February
Northern pipefish	0.003	0.06	23	October
Northern puffer	0.003	0.06	23	September
Sand lance sp.	0.003	0.06	23	July & December
Scup	0.003	0.06	23	September
Threespine stickleback	0.003	0.06	23	February & May
American eel	0.001	0.03	11	July
Atlantic cod	0.001	0.03	11	December
Atlantic moonfish	0.001	0.03	11	October
Black sea bass	0.001	0.03	11	October
Planehead filefish	0.001	0.03	11	October
Pollock	0.001	0.03	11	May
Red hake	0.001	0.03	11	October
Silver hake	0.001	0.03	11	February
Totals	0.63	15.22	5,572	

* Rates have been rounded to significant figures.

significant figures). For all fishes combined the respective rates are 0.63, 15.22 and 5,572.

The yearly rate of 5,572 fishes impinged is 30% of the 20-year (1973-1992) mean annual projection of 18,418 fishes (Table 6). This is the lowest, yearly fish impingement rate since 1983, apart form 1984, 1987 and 1988 when very low circulating water capacity was generated during a lengthy Station outage. Relatively low impingement rate years offset high impingement years, and they may be attributed to very low circulating water pump operation and/or population variances of the dominant species.

Over the 20-year period (1973-1992) it has been operating, Pilgrim Station has had a mean annual impingement rate of 2.10 fishes/hr., ranging from 0.13 (1984) to 10.02 (1981) (Table 6). Anderson et al. (1975) documented higher annual impingements at seven other northeast power plants in the early 1970's. Maine Yankee Atomic Power Company (1978), at their Nuclear Generating Station, had a mean impingement rate of approximately 58 fishes/hr. from late 1972 - late 1977. Stupka and Sharma (1977) showed annual impingement rates at numerous power plant locations for dominant species and compared to these, rates at Pilgrim Station were lower than at most other sites. However, in terms of the number of fish species impinged, Pilgrim Station displays a far greater variety than other power plants in the Gulf of Maine area (Bridges and Anderson, 1984a), perhaps because of its proximity to the boreal-temperate zoogeographical zone presented to marine biota by Cape Cod.

Monthly intake water temperatures recorded during impingement collections at Pilgrim Station were generally colder during 1992 compared to the mean monthly

Table 6. Impingement Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During 1973-1992, Assuming 100% Operation of Pilgrim Unit 1*

Year	Rate/Hr.	Rate/Day	Rate/Year	Dominant Species (Rate/Year)
1973	1.41	33.89	12,371	Clupeids** (7,473)
1974	0.58	13.85	5,056	Clupeids** (4,542)
1975	0.19	4.54	1,659	Atlantic silverside (702)
1976	6.67	160.17	58,461	Atlantic herring (45,065)
1977	1.06	25.44	9,286	Atlantic silverside (2,735)
1978	4.04	97.03	35,416	Rainbow smelt (29,357)
1979	3.24	77.69	28,280	Atlantic silverside (20,733)
1980	0.66	15.78	5,769	Cunner (1,683)
1981	10.02	240.42	87,752	Atlantic silverside (83,346)
1982	0.93	22.39	8,173	Atlantic silverside (1,696)
1983	0.57	13.65	4,983	Atlantic silverside (1,114)
1984+	0.13	3.13	1,143	Atlantic silverside (185)
1985	1.14	27.46	10,022	Atlantic silverside (3,278)
1986	1.26	30.34	11,075	Atlantic herring (3,760)
1987+	0.28	6.74	2,460	Rainbow smelt (682)
1988+	0.27	6.48	2,372	Atlantic silverside (586)
1989	0.80	19.30	7,045	Atlantic silverside (1,701)
1990	1.70	40.74	14,872	Atlantic silverside (4,354)
1991	6.27	150.48	54,925	Atlantic herring (41,419)
1992	0.63	15.22	5,572	Atlantic silverside (2,633)
Means	2.10	50.46	18,418	

*Rates have been rounded to significant figures.

**Herrings (clupeids) identified as a general category in 1973 and 1974 consisted of alewife, blueback herring and Atlantic menhaden.

+No CWS pumps were in operation 29 March - 13 August 1984, 18 February - 8 September 1987 and 14 April - 5 June 1988.

Table 7. Monthly Means of Intake Temperature (°F) Recorded During Impingement Collections at Pilgrim Nuclear Power Station, 1983-1992

	Year										
Month	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	$(\overline{X})$ 1983-1992
January	36.34	37.56	38.45	38.42	36.80	38.42	35.97	35.61	33.55	38.88	36.96
February	34.32	36.70	38.15	42.97	36.00	38.71	34.98	33.40	36.08	37.05	36.84
March	36.53	39.72	37.87	38.43	36.20	40.70	37.18	37.84	37.62	40.25	38.27
April	43.42	44.46	46.63	41.37	41.30	*	44.98	41.85	*	43.14	44.21
May	51.56	53.79	50.86	48.70	48.79	*	48.84	50.55	*	47.26	50.04
June	54.21	60.09	53.63	57.38	50.21	56.68	56.11	56.31	*	57.54	55.79
July	55.94	61.67	61.24	61.57	52.83	63.00	61.51	58.96	67.00	59.44	60.32
August	60.40	58.49	64.71	59.80	58.75	*	63.29	63.44	64.62	61.46	61.66
September	57.42	58.63	63.35	58.62	56.86	58.21	58.26	63.74	60.91	61.06	59.72
October	53.83	52.00	55.13	53.92	52.31	52.73	58.58	57.75	55.88	55.38	54.75
November	50.85	47.88	47.88	45.60	47.17	47.49	52.23	52.01	45.71	49.64	48.64
December	43.06	41.74	42.86	35.58	38.90	41.30	44.00	42.44	42.30	41.43	41.35
Mean											49.05

* Temperatures were incompletely recorded during PNPS outages in these months.

temperatures for the 10-year interval 1983-1992 (Table 7). However, May, November and December water temperatures were higher than this 10-year period's monthly means.

Overall, 1982/1983/1985/1986/1990 displayed relatively warm water temperatures, 1984/1987/1989/1991 were average years, and 1988/1992 were cold water years. Pilgrim Station intake temperatures approximate ambient water temperatures. A dominance of cold water species (i.e., winter flounder, grubby and rainbow smelt) appeared at the top impingement collections during 1992.

4.2 Invertebrates

In 774 collection hours, 587 invertebrates of 16 species (Table 8) were recorded from Pilgrim Station intake screens from January-December 1992. The annual collection rate was 0.76 invertebrates/hour. Sevenspine bay shrimp (*Crangon septemspinosa*) dominated, being captured in greatest numbers from December-March, and accounting for 48.4% of the invertebrate catch. Horseshoe crabs (*Limulus polyphemus*) and American lobster (*Homarus americanus*) represented 13.6 and 11.8%, respectively, of the total invertebrates. Unlike the fishes, the 1987 and 1988 invertebrate impingement rates were comparable to 1985, 1986, and 1989 - 1992 despite relatively low circulating water pump capacity available in 1987 and 1988.

A noteworthy occurrence was the collection of so many blue mussels during 1986-1989. This could be an effect of the Pilgrim Station outage during the late 1980s (reduced power level in 1989) which precluded the use of regular thermal backwashes for macrofouling control, and the migratory/adhesive

Table 8. Monthly Impingement For All Invertebrates Collected From Pilgrim Station Intake Screens, January-December 1992

Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
Sevenspine bay shrimp	26	172	46	10	7	1						22	284
Horseshoe crab					35	34	10	1					80
American lobster					34	11	3	10	7	3		1	69
Green crab		3				1	6	13	9	6	10	4	52
Longfin squid				1	7	8	2	9		7			34
<u>Nereis</u> sp.	2	14	2	2						2			22
Rock crab		1	4		3	1	1	1		4		3	18
Isopoda					1	6						1	8
Common starfish	1		1		1				1				4
Green seaurchin				1	2							1	4
Nemertea	1	2										1	4
Lady crab					1					2			3
<u>Maurolicus</u> <u>muelleri</u>												2	2
Artic lyre crab												1	1
Blue mussel	1												1
Flabelligera												1	1
TOTALS	31	192	53	14	91	62	22	34	17	24	10	37	587
Collection Time (hrs.)	53	78	80	53	44	55	92	70	34	54	90	71	774
Collection Rate (#/hr.)	0.58	2.46	0.66	0.26	2.22	1.13	0.24	0.49	0.50	0.44	0.11	0.52	0.76

* Undetermined numbers

abilities of mussels. In 1990 and 1991 several thermal backwashes were performed and blue mussel impingement was relatively minor for those years.

During 1992 only one blue mussel was collected from the intake screens, possibly as a result of aggressive biofouling control activities, including three effective thermal backwashes during the months of May, July and October.

Horsehoe crabs were the second most abundant invertebrate impinged, peaking in May and June, which is their primary inshore spawning period. Sixty-nine specimens of the commercially important American lobster (Homarus americanus) were captured in 1992, ranking them third. This equals 783 lobsters impinged on an annual basis at 100% operation of Pilgrim Station, under conditions at the times of impingement. This is comparable to 1991 and is a much larger number of lobsters impinged than in previous years. The lobsters ranged in size from 21-75 mm carapace length.

Approximately 5,261 pounds of mixed algae species were collected during 1992 impingement sampling for a rate of 6.8 pounds/hr. This equates to 30 tons of algae annually on Pilgrim intake screens. As expected, this rate is considerably higher than the 1984, 1987 and 1988 outage years and comparable to 1989-1991 because of regular circulating water pump availability during the last four years.

4.3 Fish Survival

Fish survival data collected in 1992 while impingement monitoring was conducted are shown in Table 9. Static screen wash collections provided the greatest numbers of fishes and revealed an overall survival rate of approximately 45%. Fishes collected during continuous screen washes fared

Table 9. Survival Summary for the Fishes Collected During Pilgrim Station Impingement Sampling, January-December 1992. Initial Survival Numbers Are Shown Under Static (8-Hour) and Continuous Wash Cycles

Species	Number Collected Static Washes	Number Collected Cont. Washes	Number Surviving (Initial) Static	Number Surviving (Initial) Cont.	Total Length (mm) Mean	Total Length (mm) Range
Atlantic silverside	227	5	64	0	109	79-145
Winter flounder	70	2	64	2	108	47-346
Grubby	42	1	32	0	74	49-121
Rainbow smelt	24	1	7	0	126	93-173
Alewife	22	0	7	-	113	72-202
Atlantic tomcod	11	0	3	-	123	106-170
Blueback herring	11	0	1	-	100	76-124
Lumpfish	7	3	4	3	48	34-80
Tautog	7	2	7	2	78	58-120
Little skate	8	0	3	-	411	241-507
White perch	7	0	5	-	123	110-155
Striped killifish	3	1	2	1	81	76-84
Atlantic herring	3	0	0	-	43	42-45
Cunner	3	0	3	-	113	49-160
Radiated skanny	3	0	3	-	116	101-137
Rock gunnel	2	1	1	0	90	62-144
Windowpane	2	1	1	1	94	88-102
Atlantic menhaden	2	0	0	-	173	76-270
Atlantic seasnail	2	0	2	-	62	45-79
Northern pipefish	1	1	1	0	157	126-167
Northern puffer	2	0	1	-	53	38-67
Sand lance sp.	2	0	1	-	103	80-125
Scup	2	0	0	-	76	42-110
Threespine stickleback	2	0	1	-	61	58-64
American eel	1	0	0	-	585	585
Atlantic cod	1	0	1	-	105	105
Atlantic moonfish	1	0	0	-	52	52
Black sea bass	1	0	0	-	83	83
Planehead filefish	1	0	0	-	170	170
Pollock	0	1	-	0	72	72
Red hake	1	0	0	-	190	190
Silver hake	1	0	0	-	134	134
All Species:						
Number	472	19	214	9		
(% Surviving)			(45.3)	(47.4)		

about the same showing a survival rate of 47%. The relatively high initial survival rate for static screen washes, compared with most years previous to 1991 (57%), was influenced by the high initial survival of winter flounder and grubby which were impinged in abundant numbers. Typically, fishes have a noticeably higher survival rate during continuous screen washes because of reduced exposure time to the effects of impingement. However, reduced intake currents in 1984, associated with limited circulating water pump operation, may have been a factor in higher static wash survival then because of less stress on impinged individuals; although this wasn't apparent from 1987 and 1988 limited pump operation results.

Among the ten numerically dominant species impinged in 1992, four demonstrated initial survival rates of 50% or greater. Tautog showed 100% survival, winter flounder 92%, grubby 74%, lumpfish 70%, little skate 38%, alewife 32%, Atlantic silverside 28%, rainbow smelt 28%, Atlantic tomcod 27% and blueback herring 9%.

SECTION 5

CONCLUSIONS

1. The average Pilgrim collection rate for the period January-December 1992 was 0.63 fish/hour. The impingement rates for fish in 1984, 1987 and 1988 were several times lower than in 1985, 1986 and 1989 - 1992 because of much reduced circulating water pump capacity during the former years.

2. Thirty-two species of fish were recorded in 774 impingement collection hours during 1992. In 1985, 1986 and 1989 - 1992 several times the number of fishes were sampled as compared to 1984 and 1988, despite more collection hours in 1984 and an average number of hours in 1988. This illustrates the importance that the number of circulating pumps operating has on the quantity of impinged organisms. Substantially less collecting hours for portions of 1987 precluded its comparison with other years.

3. At 100% yearly operation the estimated maximum January-December 1992 impingement rate was 5,572 fishes (204 lbs.). This projected annual fish impingement rate was several times lower than 1991 at Pilgrim Station when a large impingement incident of Atlantic herring occurred.

4. The major species collected and their relative percentages of the total collections were Atlantic silverside, 47.3%; winter flounder, 14.7%; grubby, 8.8%; and rainbow smelt, 5.1%

5. The peak in impingement collections for Atlantic silverside occurred during February and March. Atlantic silverside hourly impingement rate per month varied from 0 to 1.54.

6. Monthly intake water temperatures, which generally reflect ambient water temperatures, were mostly colder during 1992 than the ten-year monthly averages for the period 1983-1992. However, exceptions were May, November and December mean water temperatures which were higher than the ten-year averages.

7. The hourly collection rate for invertebrates was 0.76. Sevenspine bay shrimp (48.4%) dominated because of large December-March collections. Horeshoe crabs and American lobsters were 13.6 and 11.8% of the catch. Sixty-nine American lobsters were collected which equates to a potential 1992 impingement of 783 lobsters.

8. Impinged fish initial survival was approximately 45% during static screen washes and 47% during continuous washes for pooled species. Of the ten fishes impinged in greatest numbers during 1992, four showed initial survival rates of 50% or greater.

SECTION 6

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SUMMARY REPORT:
FISH SPOTTING OVERFLIGHTS
IN WESTERN CAPE COD BAY
IN 1992

Prepared by: Robert D. Anderson
Robert D. Anderson
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Licensing Division
Boston Edison Company

April 1993

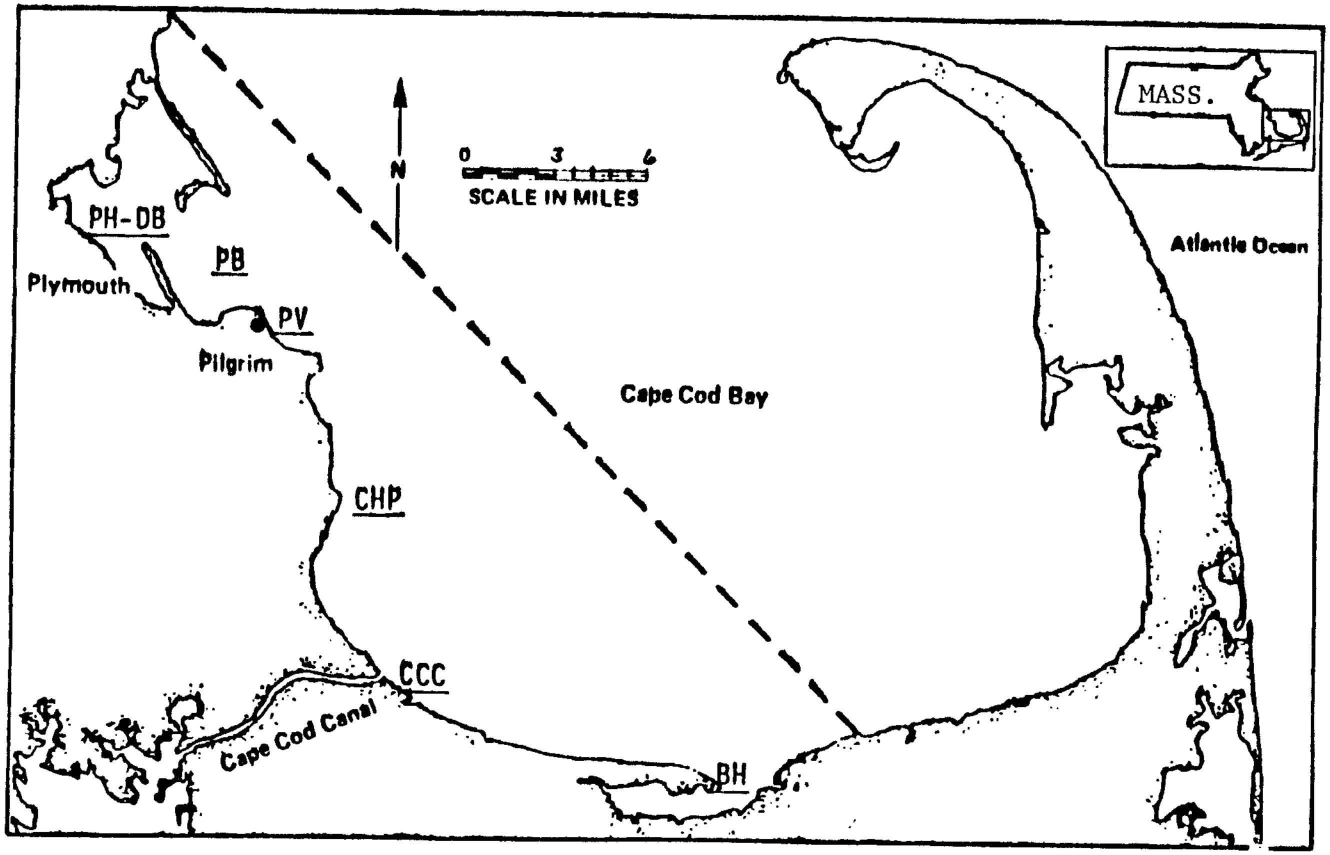
SUMMARY REPORT:
FISH SPOTTING OVERFLIGHTS IN
WESTERN CAPE COD BAY IN 1992

Weekly fish spotting overflights were made north, south and in the vicinity of Pilgrim Nuclear Power Station (PNPS) from March-November 1992. Four main groupings of fish were noted by the overflight pilot who was trained to spot fish for commercial fishing operations. The four groupings are: 1) herring, consisting primarily of Atlantic herring (*Clupea harengus*), alewife (*Alosa pseudoharengus*) and/or blueback herring (*Alosa aestivalis*); 2) Atlantic menhaden (*Brevoortia tyrannus*); 3) Atlantic mackerel (*Scomber scombrus*); and 4) baitfish, consisting primarily of any species too small to identify but most likely being composed of Atlantic silverside (*Menidia menidia*), rainbow smelt (*Osmerus mordax*), sand lance (*Ammodytes* spp.) or the juveniles of other species. In addition, sightings of other marine species, such as bluefish (*Pomatomus saltarix*) or whales (Cetacea), are occasionally reported.

Figure 1 shows the general area covered by the PNPS fish overflight program, although reports of fish concentrations are received from further north or south, also. Plates 1 and 2 show an overflight airplane and a typical fish school as it appears when viewed from the airplane.

This summary report is meant for general information purposes only, as it is not possible to quantify with reasonable accuracy the data from this qualitative program. Nevertheless, this program is very valuable and useful in being responsive to NPDES Permit requirements, documenting barrier net effectiveness when confirming large quantities of fishes in the Pilgrim area, and alerting

Figure 1. **FISH SURVEILLANCE OVERFLIGHTS (Critical Area)**



PH-DB	Plymouth Harbor-Duxbury Bay
PB	Plymouth Bay
PV	Pilgrim Vicinity
CHP	Center Hill Point
CCC	Cape Cod Canal
BH	Barnstable Harbor

Note: Critical surveillance area is west of the dashed line in the vicinity of the specific locations noted. Generic observations should also be made in the course of the plane's flight to and from the critical area.

Plate 1. The airplane used for fish spotting overflights in the Pilgrim Station area is typical of the ones used in commercial area fishing operations.

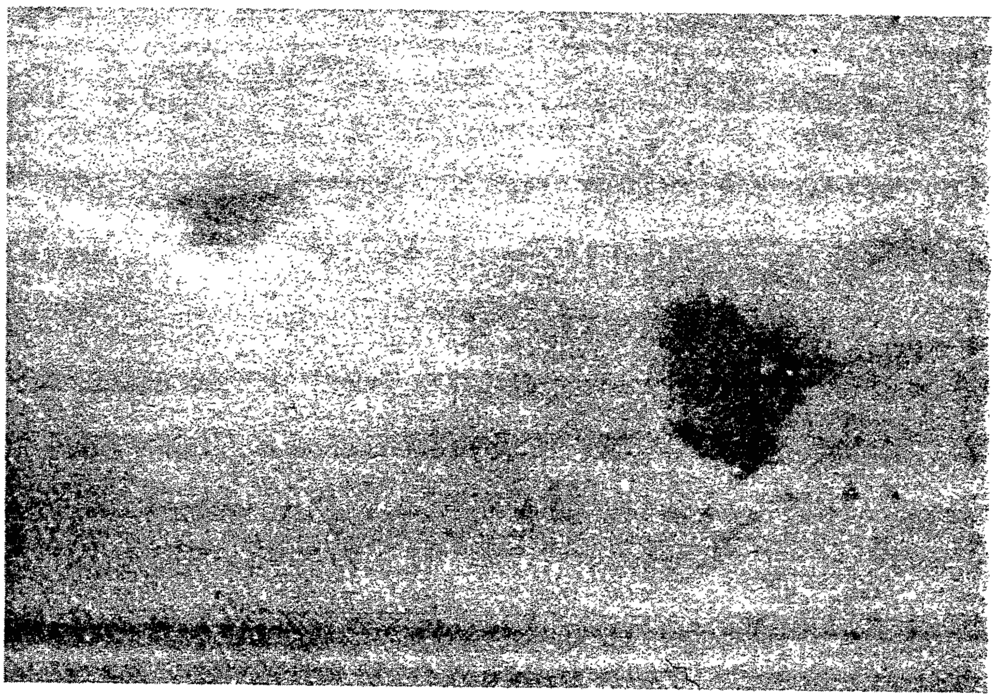


Plate 2. A fish school appears as a dark shadow from the airplane, and it takes an experienced pilot to distinguish its composition from submerged objects.

Boston Edison Company and regulatory personnel of the potential for a discharge-related fish mortality.

Table 1 summarizes location, approximate poundage and seasonal information for the four groupings of fishes defined above. Below are some interpretive comments based on general trends illustrated by fish observation data for the four predominant fish groups from March-November 1992:

1. Herring - This is a mixed species category, but the majority of pounds of herring observed by fish overflights represents Atlantic herring as borne out by commercial catch statistics. This species was in the Cape Cod Bay region during most of the observation period, primarily in the vicinity of PNPS. The alewife and blueback herring were spotted throughout Cape Cod Bay from late April - mid May when they are on spawning migrations. However, most of the herring observed were Atlantic herring with a relatively large number of sightings of them during 1991 and 1992 in the vicinity of PNPS, possibly reflecting population fluctuations for this species. Nine observations of Atlantic herring within a few miles of PNPS were made during 1992, including over 100,000 pounds on two dates, April 6 and 12. No fish mortalities occurred, although in November 1976 over 10,000 Atlantic herring were killed by impingement on PNPS intake traveling screens.

2. Atlantic Menhaden - This species is of concern at Pilgrim because of past gas bubble disease mortalities in the discharge canal and thermal plume. As can be seen from Table 1, menhaden may occur over

TABLE 1. Approximate Location, Relative Species Poundage and Seasonality from Fish Observation Overflights in the Western Cape Cod Bay Area in 1992

LOCATION	SPECIES	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
North of Pilgrim	Herring		25,900	51,000		320,000			136,000	90,000
	Menhaden			4,135,000	670,000	464,000	135,000	55,000	55,000	
	Baitfish			2,000						
	Mackerel			115,000				3,000	10,000	3,000
Pilgrim Vicinity	Herring		630,000			60,000		90,000	100,000	25,000
	Menhaden			1,130,000	745,000					
	Baitfish									
	Mackerel							145,000		
South of Pilgrim	Herring	4,000	10,000	80,000	95,000			54,000		
	Menhaden			85,000	230,000					
	Baitfish					15,000				
	Mackerel			10,000	10,000				10,000	
Totals	Herring	4,000	665,900	131,000	95,000	380,000		144,000	236,000	115,000
	Menhaden			5,350,000	1,645,000	464,000	135,000	55,000	55,000	
	Baitfish			2,000		15,000				
	Mackeral			125,000	10,000			148,000	20,000	3,000

* Regulators notified (EPA/DWPC).
\+ Unestimated poundage.

the entire Cape Cod Bay region in millions of pounds from spring through early fall. Overflight pilots are particularly adept at identifying this species as commercial ventures depend heavily on accurate observations for success. The first menhaden north of Cape Cod in 1992 were observed on May 11 in the vicinity of PNPS. The great majority of menhaden were sighted north of PNPS from May through October. Menhaden were spotted in the PNPS vicinity on May 11 (570,000 pounds) and May 19 (560,000 pounds) and in smaller numbers on several dates in June. Regulatory agencies (EPA and Mass. DWPC/DMF) are notified when fish are within 1/2 mile of the point of thermal discharge into Cape Cod Bay. The last menhaden observed in 1992 were 55,000 pounds off Duxbury Beach on October 12.

3. <u>Atlantic Mackerel</u> - These fish support a valuable commercial fishery and were reported most frequently north of PNPS. In 1992, there were several observations made of Atlantic mackerel schools from May - November with largest quantities seen in September. There were two sighting dates close to PNPS when 20,000 pounds were spotted on September 13 and 125,000 pounds on September 25 in the Station vicinity.

Mackerel occur in relatively large numbers usually during the Summer - early Fall months, and no notable incidents involving them have occurred at Pilgrim Station. They are an offshore species for the most part but have been observed in previous years schooling in the PNPS intake embayment, where bluefish predation on them has occurred.

4. Baitfish - This category is a catchall and may include large numbers of small unidentified fish. On July 3 several thousand pounds of sand lance were seen off Barnstable Beach with bluefish probably feeding on them. Sand lance, as well as most species in this grouping, regularly inhabit the PNPS intake area in numbers too small to be seen by overflights but recorded during seine net sampling from the intake beach.

   Baitfish could represent the offspring of fishes in the above categories as well as Atlantic silversides, rainbow smelt and sand lance. Some of these species are significant in impingement collections at PNPS.

5. Other - There were several other spottings made in 1992 which fall outside the above categories. Included were bluefish, finback whales, striped bass, and basking sharks. Those species seen in the proximity of PNPS included striped bass in May, June and September; finback whales in April and June; bluefish (200,000+ pounds) in June and July; and one basking shark in June.

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MEMORANDUM

TO: Members of the Administrative-Technical Committee, Pilgrim Power Plant Investigations

FROM: Brian Kelly, Recording Secretary, Massachusetts Division of Marine Fisheries

SUBJECT: Minutes of the 78th meeting of the Pilgrim Administrative-Technical Committee

DATE: October 20, 1992

The 78th meeting of the Pilgrim Administrative-Technical (A-T) Committee was called to order by Chairman Szal (DWPC) on September 29, 1992 at 10:20 a.m. at the Richard Cronin Building, Massachusetts Division Fisheries and Wildlife Field Headquarters, Westboro, Massachusetts. Seven agenda items were addressed.

I. Minutes of the 77th Meeting

There were no additional comments on the previous A-T meeting minutes, which were accepted unanimously.

II. Pilgrim Station Status Update

Bob Anderson mentioned that from January through August of 1992 Pilgrim Station ran at 90% capacity. There will be a thirty day mid-cycle outage from October 24 through approximately November 24. Plant operational status is projected to be 85% in 1992 versus 58% in 1991 and 78% in 1990. A table of historical plant operational levels is sent with the minutes of this meeting to A-T members (attached).

There was one event this summer where Pilgrim slightly exceeded there 32° F T; EPA was promptly notified of this permit violation. A brief discussion on discharge violation reporting logistics followed.

III. <u>1993 Benthic Monitoring Program</u>

Don Miller requested Chairman Szal to contact Coastal Zone Management regarding a replacement for Judy Pederson on the full A-T Committee and Benthic Subcommittee. Don discussed the minutes from the recent Benthic Subcommittee meeting. Dr. David Aubrey, a coastal oceanographer from Woods Hole Oceanographic Institution (WHOI) who also has his own consulting firm, will be submitting a formal proposal shortly to study the areal extent of the Pilgrim discharge plume's contact with the bottom. Dr. Rocky Guyer, physical oceanographer at WHOI, also will be involved. Temperature and current measurements will be taken for a 30-day period in late winter and again in late summer to document the extremes in temperature at the Pilgrim Station site. These data will be incorporated into a stochastic model to describe plume movements. Aubrey may do a preliminary deployment for plume mapping after the mid-cycle outage is over in late November to test this design.

Don's belief is that if plume contact with the bottom proves to be small, then the A-T Committee can proportionally limit the extent of the far-field biological studies. Don emphasized that Aubrey and Guyer have the expertise and equipment to perform shallow water plume studies such as at Pilgrim Station. The Full A-T Committee agreed that the Benthic Subcommittee should review Aubrey's proposal, vote on it, and, if acceptable, request final approval by the Full A-T Committee via telephone or mail.

Routine qualitative benthic monitoring at Pilgrim was recommended by the Benthic Subcommittee to continue unchanged through 1993. Bob Maietta motioned to accept this recommendation and for the work to be done by SAIC; Jan Prager seconded the motion, which carried unanimously.

IV. <u>1993 Marine Fisheries Monitoring</u>

Bob Lawton noted that, in an effort to address the concerns of Jack Paar and other members of the Fisheries Subcommittee, the Division of Marine Fisheries (DMF) has redirected its monitoring proposals toward an indicator species approach. The first species of concern is lobster, which is entrained and impinged in very low numbers at Pilgrim. Any possible plant impact would be in the discharge area, which probably would be a small exclusion area of no more than an acre. Bob mentioned that the Fisheries Subcommittee agreed that the commercial lobster-pot study can be dropped. Bob described proposed changes in the research lobster study concerning trawl deployment next year. Several Committee members felt that the redesigned research lobster study compliments what Aubrey and Guyer will be researching next year. Ted Landry emphasized that a conclusion should be reached definitively regarding possible lobster exclusion in the discharge area before the study is terminated.

Carolyn Griswold motioned to drop the commercial lobster study, which passed unanimously (DMF abstained from voting). Bob Maietta then moved to accept the revised research lobster study to be done by DMF, seconded by Carolyn, and passed unanimously (DMF abstained).

Bob Lawton presented an overview of the ongoing studies of a second indicator species, cunner, in the Pilgrim area, including results of some adult equivalency estimates from entrainment sampling (22,000 fish) and population estimate efforts for the Pilgrim outer breakwater from tag and recapture information. Bob Maietta motioned to continue the cunner study as proposed, including the diving surveys, to be done by DMF. Carolyn seconded the motion, which passed unanimously (DMF abstained).

Bob Lawton then discussed the third indicator species, winter flounder, touching on a preliminary adult equivalency estimate (20,000 age 3+ fish) generated from Pilgrim entrainment data and the possibility of stock estimates using area swept with the DMF trawl and the diving transects. A discussion followed on future flounder assessment needs based on the recent Brayton Point meeting. Carolyn moved to accept the trawl and dive surveys as proposed to be performed by DMF; Bob Maietta seconded the motion, which passed unanimously (DMF abstained). Bob Lawton requested that the Committee consider for the future an evaluation of the fisheries studies as was done recently for benthic studies.

V. <u>1993 Impingement/Entrainment/Overflight Monitoring</u>

Carolyn briefly presented the proposed entrainment/impingement sampling for Pilgrim Station. Jack motioned to accept the proposed sampling to be done by MRI, Bob Maietta seconded the motion, which passed unanimously. Future changes to entrainment/impingement sampling will depend on outcome of Brayton Point investigations.

Carolyn mentioned that the fish overflights were given a low priority by the Fisheries Subcommittee. A motion was made to continue the flights as proposed with Corregio Spotting Services, which passed with one abstention.

VI. <u>Radiological Monitoring Program Review</u>

Ken Sejkora discussed use of the blue mussel to monitor radiation exposure at Pilgrim, and talked at length on the interpretation of Cobalt-60 and Cesium-137 levels in environmental samples.

VII. <u>Other Business</u>

The Full Committee had a discussion concerning the merits of recommending the retention of the same contractors from year to year to perform environmental monitoring at Pilgrim Station. The long-term environmental monitoring studies performed to date at Pilgrim have employed relatively consistent sampling practices and analytical techniques, thus insuring data integrity and reliability, and fostering valid conclusions concerning potential and real power plant impacts. As noted in the minutes above, the contractors for each monitoring effort have been endorsed to perform the studies at Pilgrim as they have historically done quality work in the opinion of the A-T Committee. As in the past, the Committee felt strongly that to maintain long-term data comparability of the environmental monitoring efforts at Pilgrim Station, necessary in decision making, these contractors should continue to be retained.

VIII. Adjournment

The meeting adjourned at 2:15 PM.

Pilgrim Administrative-Technical Committee Meeting Attendance

September 29, 1992

Gerald Szal, Chairman	Mass. DEP, Grafton
Ted Landry	EPA, Boston
Don Miller	EPA, Narragansett
Jan Prager	EPA, Narragansett
Jack Paar III	EPA, Lexington
Robert Maietta	Mass. DEP, Grafton
Carolyn Griswold	NMFS, Narragansett
Robert Anderson	BECo, Braintree
Kenneth J. Sejkora	BECo, Plymouth (guest)
Robert Lawton	Mass. DMF, Sandwich
Leigh Bridges	Mass. DMF, Boston
Brian Kelly	Mass. DMF, Sandwich (recording secretary)

Pilgrim Nuclear Power Station Unit 1 Capacity Factor Using MDC Net%
(Roughly approximates thermal loading to the environment: 100% ~ 32°F∆T)

Month	1992	1991	1990	1989	1988*	1987*	1986	1985	1984*	1983	1982	1981	1980	1979	1978
January	96.6	95.4	99.4	0.0	0.0	0.0	79.5	54.0	0.0	98.0	0.0	85.7	11.8	98.2	10.9
February	99.4	88.9	97.4	0.0	0.0	0.0	97.7	59.3	0.0	90.0	0.0	67.0	0.0	95.4	59.9
March	80.4	84.6	30.0	10.7	0.0	0.0	26.9	81.8	0.0	97.3	0.0	65.6	0.0	80.2	90.2
April	53.5	92.7	5.4	10.5	0.0	0.0	11.9	90.8	0.0	89.7	44.1	90.7	0.0	99.0	66.8
May	97.8	0	77.9	4.6	0.0	0.0	0.0	94.3	0.0	97.3	80.1	94.6	20.8	38.0	75.8
June	97.8	0	96.3	16.4	0.0	0.0	0.0	85.0	0.0	66.2	87.5	95.0	83.1	90.3	97.0
July	97.4	0	55.1	28.6	0.0	0.0	0.0	96.9	0.0	80.5	97.2	59.8	87.7	53.8	85.7
August	97.4	28.5	94.5	50.8	0.0	0.0	0.0	96.5	0.0	83.1	75.7	72.1	78.7	85.7	91.0
September	90.1	96.4	21.6	52.5	0.0	0.0	0.0	71.4	0.0	86.5	68.3	75.4	93.4	78.6	93.8
October		94.2	98.7	30.1	0.0	0.0	0.0	95.4	0.0	79.0	39.9	0.0	74.9	83.9	34.9
November		23.7	96.8	66.0	0.0	0.0	0.0	88.1	0.0	78.6	88.9	0.0	68.4	96.7	95.5
December		98.1	94.5	77.1	0.0	0.0	0.0	99.1	0.7	18.1	87.1	0.0	99.6	93.2	94.8
ANNUAL %		58.4	72.3	28.9	0.0	0.0	17.5	84.4	0.1	80.3	56.0	58.7	51.7	82.5	74.6

CUMULATIVE CAPACITY FACTOR (1973 - 1991) = 47.4%

__________ = OUTAGES

* = NO CIRCULATING SEAWATER PUMPS IN OPERATION FROM 27 MARCH - 13 AUGUST, 1984
= NO CIRCULATING SEAWATER PUMPS IN OPERATION FROM 18 FEBRUARY - 8 SEPTEMBER, 1987
= NO CIRCULATING SEAWATER PUMPS IN OPERATION FROM 14 APRIL - 5 JUNE, 1988

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